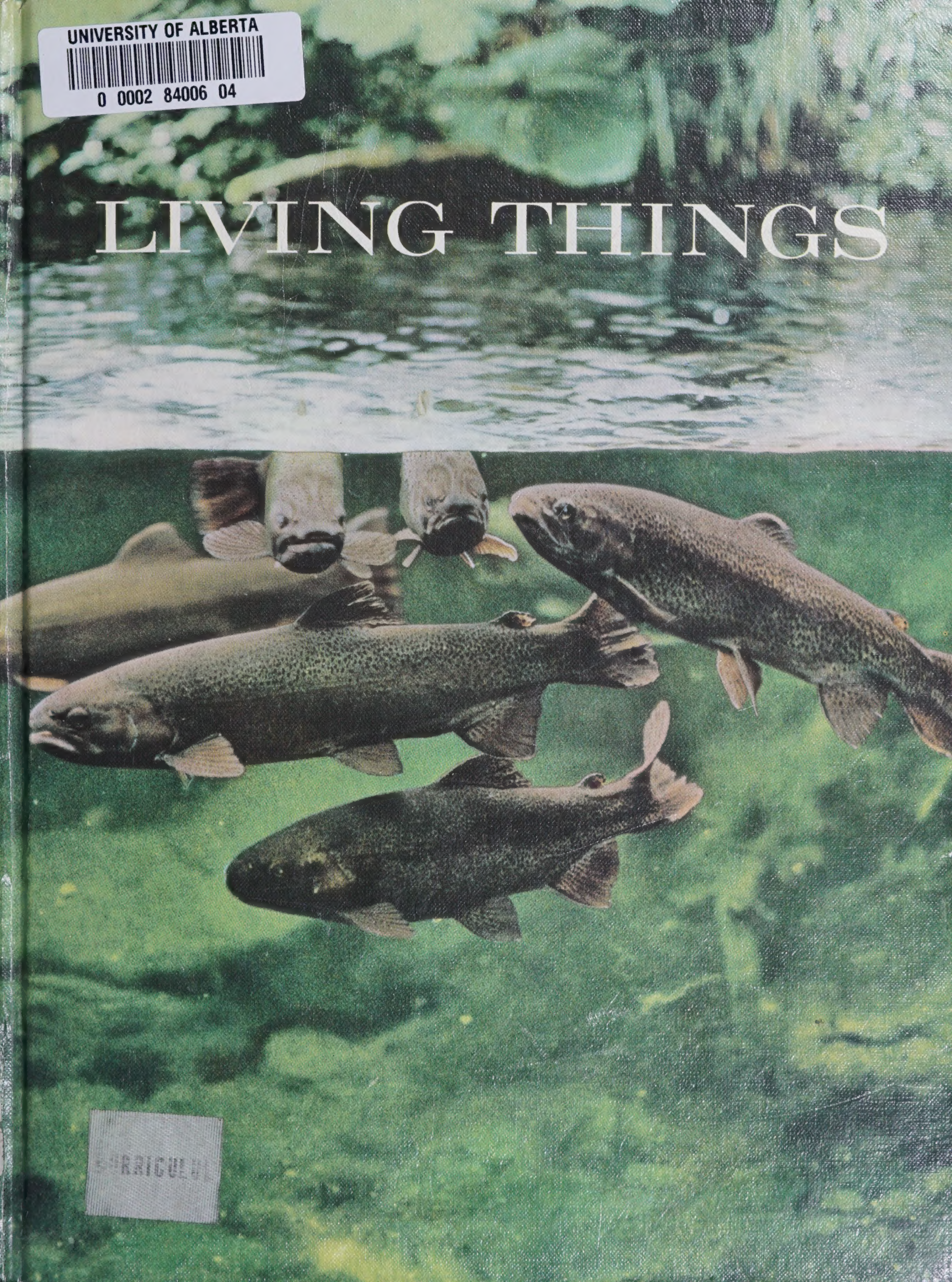
LIVING THINGS



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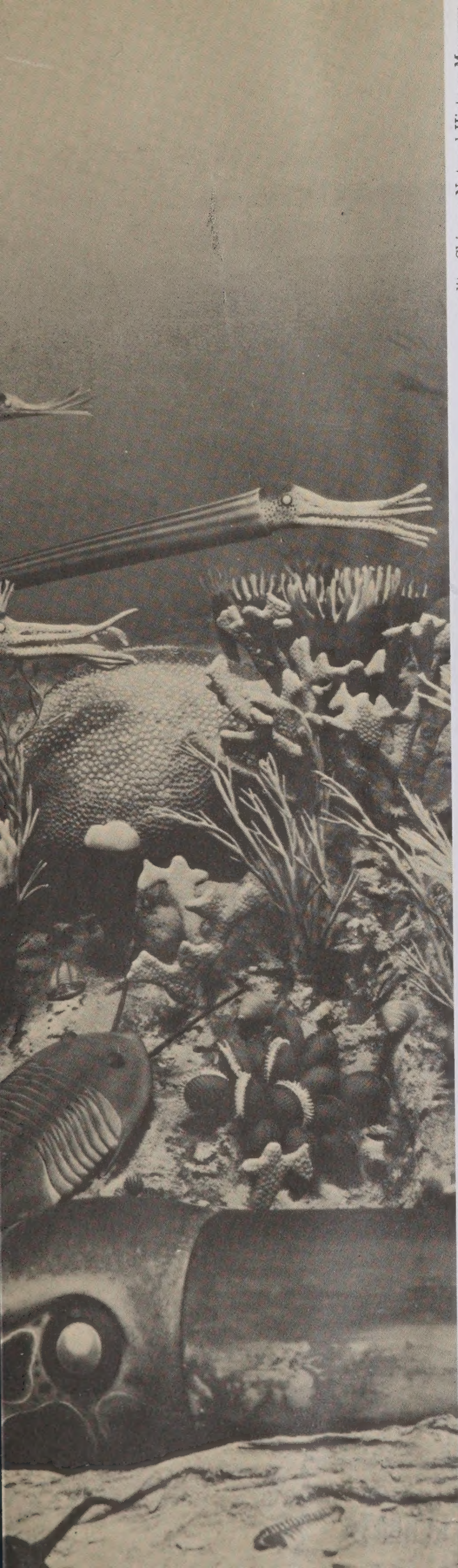

credit—Chicago Natural History Museum

Living Things

Frederick L. Fitzpatrick

Harold E. Teter

Thomas D. Bain

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THE AUTHORS

FREDERICK L. FITZPATRICK is Professor Emeritus of Natural Sciences and formerly Head of the Department of Science Education at Teacher's College, Columbia University, New York City

Harold E. Teter is Head of the Science Department at Cooley High School, Detroit, Michigan

THOMAS D. Bain is a teacher of biology at Harding High School, Marion, Ohio

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Unit opening photographs
1 Harold E. Teter
2 R. H. Noailles
3 Grant Haist
4 National Institute of Dental Research
5 R. H. Noailles
6 Williams, National Park Service
7 World Health Organization

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PREFACE

Young people learn some things about biology both in school and out of school. They begin to study plants and animals in elementary science. They also have experiences with living things in their environment, whether they live in the city, the suburbs, or a rural area. Many of them develop interests in plants and animals because living things are so much a part of their lives.

No matter what the students do in adult life, they will come face to face with various problems. Many of these problems will involve the nature and activities of living things. To solve them in a satisfactory manner, it is necessary to have a basic comprehension of biological concepts, and the facts that support these concepts. LIVING THINGS has been organized with definite emphasis upon the functional materials of biology—the materials that relate to everyday experiences. The criterion for selection has been the question: Is this material significant; is it related to the needs and interests of students as they confront their daily concerns? We believe that the result is a book that supports the general or liberal education aim, and presents the phases of life science that young people need to know.

One of the purposes of instruction is to broaden student experiences and knowledge. All people should realize that they are a part of the living world, and that what happens in the city, the field, or the forest affects their well being, no matter where they reside at the moment. Moreover, it is well known that our human population is constantly moving about. The urban dweller goes to the country, and the rural resident comes to the city. People go back and forth from east to west, and from north to south. But wherever they are, the basic concepts of biology have application and meaning. In any setting there are problems of food production, water supply, wise use of resources, health, and many others.

In using the program presented in LIVING THINGS the teacher may exploit the existing interests of students. These interests will often serve as a natural introduction to the subject matter. Once instruction is under way, the teacher may wish to employ certain technical terms that have not been included in the text book, depending upon the progress that the student group is making. At all times there may properly be an emphasis upon scientific methods, or the ways in which biological knowledge is constantly being extended and refined. There may also be an effort to cultivate desirable attitudes toward learning in general, as well as the scientific approach to problem solving.

Units 1, 2, and 3 present a number of fundamental concepts relating to cell organization and function, reproduction, heredity, natural selection, and ecological relationships within the natural community. In these first three

units, the various concepts are introduced; they are extended and amplified in the remaining units of the book. Unit 7, for example, applies these basic concepts to human structure, human functions, and health maintenance. Each of the last four units is rather complete in itself, and depending upon circumstances, the teacher may elect to change the order in which they are studied.

Within recent years research dealing with protein molecules has given biology what is sometimes called a "molecular dimension". Related progress has come from the use of electron microscopes, which have revealed certain cellular structures for the first time. Some attention is given to these discoveries in Unit 1. Much of the new information, however, is rather technical. For the benefit of more advanced students, some of this material concerning nuclear biology has been summarized in the Appendix.

Certain activities involving observations and simple experiments are described at the ends of most of the chapters in this book. The teacher may wish to employ some of them as demonstrations, and assign others to students as individual or group work. These activities, however, are not intended to be a complete laboratory guide for the course. Such a guide is provided by a separate publication entitled INVESTIGATIONS OF LIVING THINGS.

Laboratory work can be a very significant phase of the learning experience when time and proper facilities are provided. It serves to increase the students' enjoyment and acceptance of the course. It gives the students direct experience with the processes scientists use in obtaining their facts and developing their theories. This is desirable because it fosters the education of future scientists, and it serves to free others from the tendency to regard science as "space-age magic".

A new item in the field of audiovision has been added to the biology course. The Holt Biology Film Loops have been specially produced for the biology program as it is usually offered in today's schools. These exquisite films have been designed to encourage proper individualized field studies and laboratory techniques. Many of the films are ecologically oriented to help students to become aware of the diversity of form, function, and adaptation of organisms and to stimulate interest in those outdoor activities which are related to biology. Even in the country few teachers can find an animal or a plant at the exact time it should be studied, but the film loops make such study possible.

The films can be used as classroom presentations by the teacher, or as independent study sources by the students, or as a combination of both. Due to the fact that the running time of each loop is less than five minutes, it is possible for students to rerun the film as often as they wish. Stop action on any frame is also possible to accomodate individual needs or differences.

Study guides call the student's attention to things he might have missed during the first viewing. They also provide additional topic information and ask a series of open-ended questions that stimulate deeper thought. The

guides are illustrated with black-and-white still photographs from the films themselves.

When you wish to show such topics as parasite-host relationships, adaptations of plants and animals, the diversity of living things, or various environmental conditions, the film loop is a superb teaching tool. These loops are also valuable because they illustrate in detail the biological techniques of collecting, of field study, and of laboratory experimentation using student actors for human interest. For further information write the publisher of this textbook.

But gaining facility in field and laboratory procedures is only one facet of the biological experience. The overall aim is to introduce students to the broad areas of biological lore, including methods, knowledge, and concepts, with particular emphasis upon materials that are likely to be functional in present and future experiences. LIVING THINGS outlines a program that will serve this purpose.

Grateful appreciation is expressed to the following teachers and administrators who have read the manuscript and offered many valuable suggestions for its improvement: Miss Anna D. Muehleck, Chairman of the Science Department, Colone Central High School, Albany, New York; Mr. F. J. Arsenau, Chairman of Biology, Arlington Heights High School, Fort Worth, Texas; Mr. Charles C. Henderson, Educational Consultant for Science, Instructional Services Center, Montezuma, Georgia; Mr. Ralph Havickhorst, Chairman of the Science Department, Saddleback High School, Santa Ana, California; and Mr. Harvey Petty, Bloomington Junior High School, Bloomington, Illinois.

The photographs used in this edition were obtained by Miss Gabriele Wunderlich.

PREFACE FOR THE STUDENT

Learning can be a real pleasure, but only if you know HOW to learn. First, you must know how to use a book. You must be able to get the most from the book. So turn to the TABLE OF CONTENTS on pages vii and viii. You will see that this book contains seven units. Each unit deals with some phase of biology. Now note that a unit is divided into several chapters.

The first two units in the book deal with some simple facts, such as what living cells are, and how they work. These units also discuss reproduction, heredity, and what biologists call natural selection. Then in Unit 3 some of the wonderful relationships among plants, animals, and man are explained. In the rest of the book you will read about various plants, various animals, and man himself. In all of this you will be learning ways in which living things affect your everyday life.

Next, turn to Chapter 1 on page 4. Your teacher may assign all of this chapter at one time, or only part of it. Whatever the assignment is, read it carefully. Also, look at the pictures and drawings. They often are an important part of the story. Sometimes a good picture is worth a thousand words.

As you read Chapter 1, notice the words that are printed in ***heavy, black type*** like these. You must learn what these words mean. When you know, your biology course will be easier and more interesting. They are words that will appear again and again in later chapters.

At the ends of many chapters various ACTIVITIES are suggested. Ask your teacher what you should do about them. Now and then your teacher may carry out one of the activities in class. Other activities may be assigned to you.

At the end of each chapter you will also find a group of questions under CHECK YOUR FACTS. These are really self tests, but they may also be assigned to you as homework. Now suppose that you have studied Chapter 1. One way to use the questions is as follows. Take a sheet of paper and try to write out answers to all of the questions. Do not be too upset if you cannot answer one or two of them the first time you try. Check back over the chapter.

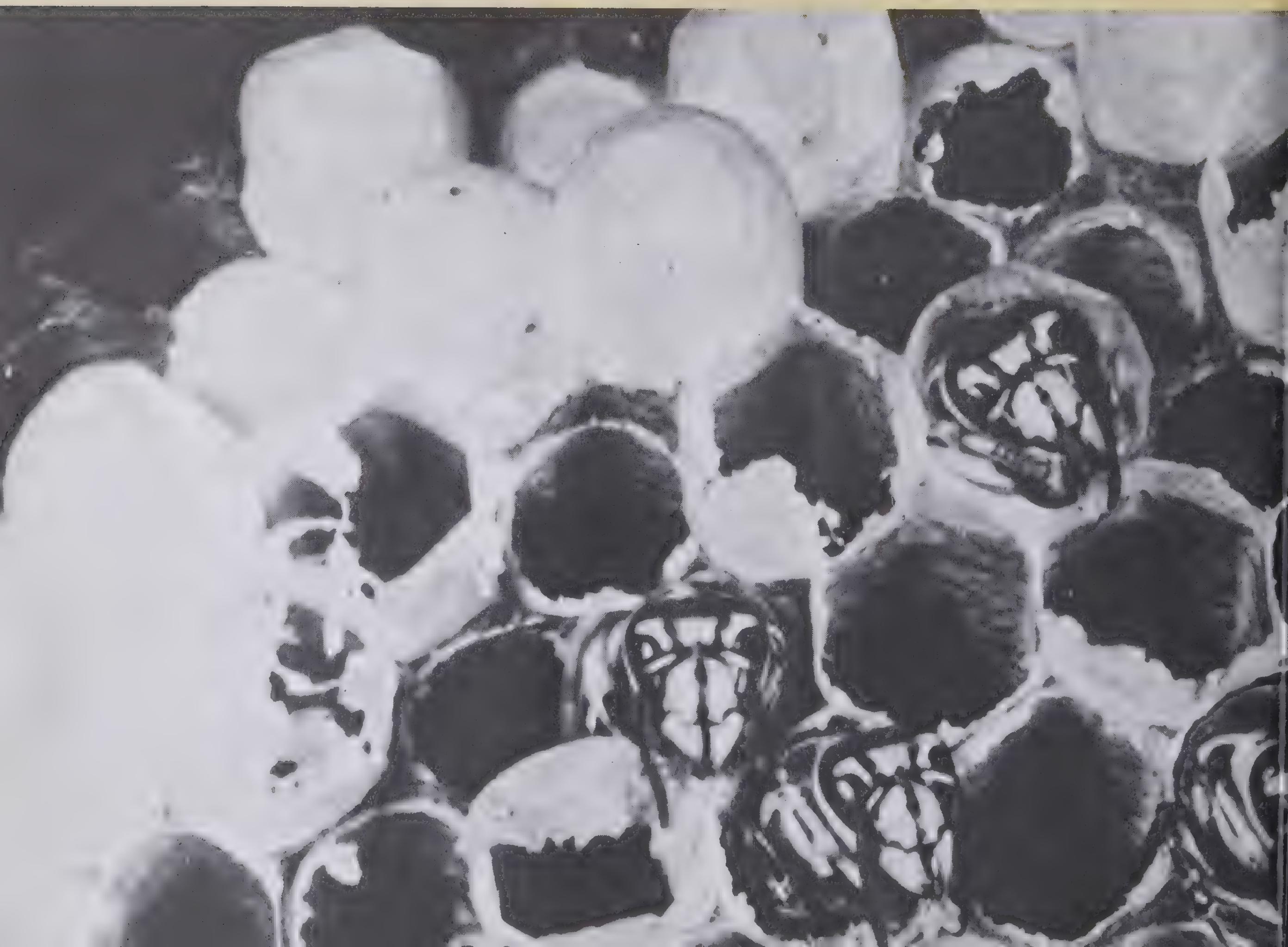
The GLOSSARY at the end of the book is a lot like a dictionary. But it lists only special words that biologists use. When you see such a word and do not know its meaning, turn to the glossary pages. If you want to learn even more about the word, look it up in the INDEX, which also is at the end of the book.

Finally, you may be interested in certain topics, and want to read more about them. Your classmates may be interested in other topics. Such special interests are not the same for all people. Your teacher and your school librarian will be glad to direct you to books telling what you want to know.

Living Things

UNIT 1

Principles Of Biology



Biology is the science in which we study living things. What makes living things different from nonliving ones? What are living things made of? How is the living substance organized? Where does food come from? How is it used in living things?

These are a few of the questions we might ask as we set out to study biology. You will find many of the answers to them in this first unit. You will also learn something of the methods used by scientists to find the answers to such questions.

CHAPTER 1

What Is Science?

Biology is a scientific subject so first of all, let us think about science in general. What is it? What is a scientist? What does he do? This last question is the easiest to answer.

A bricklayer lays bricks. A teacher teaches. A cook cooks, and a toolmaker makes tools. We call the people who do these things bricklayers, teachers, cooks, and toolmakers. Each has a particular kind of job. So does the scientist.

The scientist's job. Suppose you wish to know the answer to a question. Where do you get the answer? Very likely you ask someone whom you think can give it to you. This may get answers for some of your questions but not for all of them. It is not that easy! If no one you know can give an answer you may decide to go to the library to look it up in a book. There are many kinds of libraries, including school and neighborhood ones. There are also big libraries in the cities. There may even be special science libraries which contain recent information on scientific subjects. In all these places you will find librarians who are glad to help you. In this way it is possible for you to find the answers to *most* of your questions.

Once in a while the library may fail you. The answer you seek is not in any book or magazine nor is it known by any of your friends. The answer to your question seems not to be known by anyone.

At this point you might give up but this is where the scientist's work begins. His job is to search for new information. Scientists are in the business of increasing human knowledge. They are trying to understand and to describe the universe in which we live. The work of any one scientist may be useful to us in some practical way, or it may merely increase our understanding.

We have answered our question of what a scientist is and what he does, but what is science? It is several things. First, it is the activity of all scientists as they seek new knowledge. Second, it is the whole mass of knowledge already discovered by scientists. Third, it includes the formation of theories which try to explain what newly discovered facts mean. These theories often change as the new facts lead to new understandings.

The branches of science. Scientists work on many different kinds of problems. This makes it possible to divide science into several different fields of study.

Biology is the study of living things.

Chemistry is the study of what materials are made of and how they are put

together. **Physics** includes the study of energy in its various forms—such as electricity, light, heat, and mechanical motion. **Astronomy** deals with the sun, the planets, and the stars. It tries to explain the universe as a whole. **Geology** is the study of the earth itself—its rocks, hills, and valleys, as well as erosion and volcanoes. **Ecology** is a study of the relationships of all living things—plants, animals, and man.

Many scientists do not work in just one of these fields. The **biochemist**, for instance, studies the chemistry of living things. This is a combination of chemistry and biology. The **biophysicist** studies physics as it applies to biology.

Scientific methods. The scientist starts with some sort of idea or guess as to what the answer to his problem may be. Then he sets out to test or to check or to observe the thing he is studying. He tries to prove that something is true or untrue before he will say that he has found the answer.

The scientist often uses experiments. A famous example of how to use an experiment took place in Italy nearly 400 years ago. An Italian named ***Galileo*** (gal-i-*lee*-oh) made a statement about how objects fall. Many very important men argued with him. They said heavy objects fall faster than lighter ones. They showed him books to prove they were right. Galileo took two iron balls. One weighed several times as much as the other. He dropped them from the Leaning Tower of Pisa at the same time. They fell side by side and hit the ground together. Both balls had fallen at the same speed. This was just what Galileo had said the balls would do.

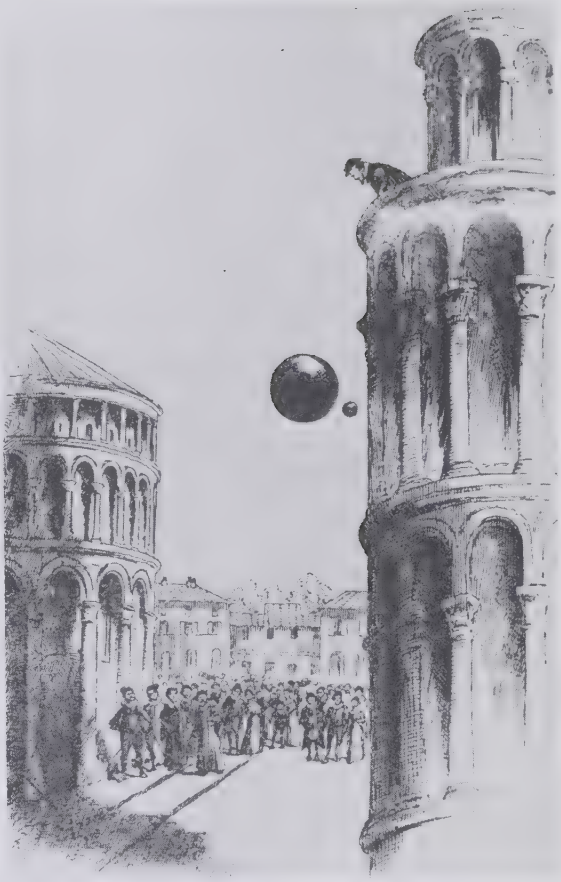


Fig. 1-1. An artist's idea of Galileo dropping the two iron balls from the Leaning Tower of Pisa. (The Bettman Archive)

Other men tried the same kind of experiment. They got the same result. In time they were forced to agree with Galileo.

Galileo's experiment sounds simple, and it was. It was also very important. It made educated men all over the world take notice. Here was a new way of finding answers! Here was a different way of settling arguments. If they wanted to know about something they could study the problem itself. They did not need to depend on books and opinions. They could experiment personally to find answers. Galileo was not the first scientist, but he did a

great deal to get science started. He showed people how to use experiments and observations. He also showed them how to form theories to explain the facts. The theory that he worked hardest on was that the earth and other planets move in paths around the sun. Today we know this is a fact, but in Galileo's time it was a very startling idea.

Another very famous experiment took place in 1881. A Frenchman named Louis Pasteur had developed a new vaccine. He thought it would keep sheep from getting a disease called anthrax. How could he be sure? Here is how he set up his experiment. He put 24 sheep from a flock in one pen and 24 sheep from the same flock in another pen. The sheep in one pen were given shots of the new vaccine. The sheep in the other pen were not vaccinated. Otherwise both pens of sheep were treated exactly alike. Later all the animals in both pens were given anthrax germs to see if they would get sick. All the vaccinated sheep stayed well. All the unvaccinated sheep died.

The important thing to notice in this experiment is the way Pasteur used the two groups of sheep. They were as alike as two groups of sheep can be. They were treated exactly alike except for one thing—only one group was vaccinated. This was the experimental group. Since vaccination was the only thing that was different, it must be the reason why the experimental group lived. The other sheep were the control group. They showed what would have happened to the experimental group if they had not been vaccinated. Using controls is important in many experiments. If Pasteur had not used controls, people might have said, "Those sheep would have lived anyway. The vaccine had nothing to do with it."

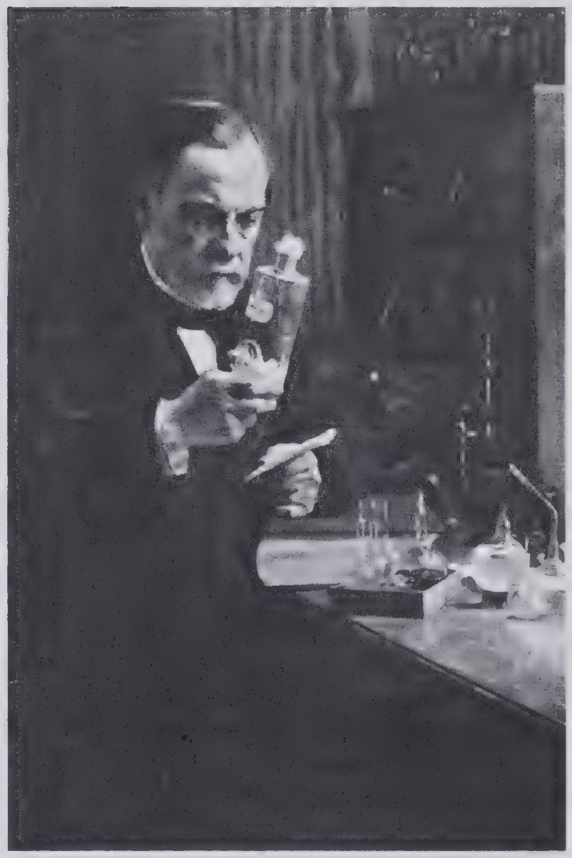


Fig. 1-2. Louis Pasteur. This great scientist used many experiments in his study of bacteria and disease. (The Bettman Archive)

Other methods of science. Experiments are not always necessary nor are they always possible.

If a biologist wants to know what pheasants eat he will depend mostly on simple observation. He may examine the stomach contents of dead pheasants to see what the birds have eaten. He may watch pheasants as they hunt for food. He will do all these things at different times of the year, in case the birds' eating habits change. He will keep careful records of all this and when finished, he will know a

great deal about the food habits of pheasants. Many problems in biology are solved in this way—by observation.

A scientist often does his work in six steps:

1. First, he gets clearly in mind what it is that he wants to find out.

2. Next, he uses books and magazines to find out what is known.

3. Then he makes the best guess he can as to just what he believes the answer may be. Perhaps he can only guess that certain activites may lead to the answer.

4. Then he performs experiments or makes observations to see if his guess is correct. If not, he makes a new guess and tries again. The outcome of these experiments or observations are his **results.**

5. Now he tries to decide what these results have proved. In other words, he draws his **conclusions.** He tries to be honest about this. He will not claim that his conclusions are facts. He will simply say that his conclusions are what he thinks the facts mean.

6. Finally, the scientist writes a description of his work and has it published. There are many special maga-

Fig. 1-3. These students learn how to use scientific methods in their school laboratory. (Shelton-Monkmeyer)

zines which contain only the results of scientific research. These magazines are read by other scientists all over the world. They use new discoveries to help them make more discoveries. This is one reason why scientific knowledge has grown so rapidly. Each scientist begins where the last one left off. One of the world's greatest scientists gave credit to the men who had gone before him. He said, "If I have seen further than other men, it is because I stood on the shoulders of giants."

Where does the scientist work? Scientists do their work in many places. Ever since the time of Galileo much of the best scientific work has been done in the science departments of universities. These schools not only carry on scientific research, but train new young scientists. A country that does not have good schools cannot keep up its scientific program.

Another place where scientists work is in industry. All of the large manufacturing companies hire scientists. The scientist in a university often does basic research to discover new facts and scientific laws. Many scientists in industry apply these facts and laws to the development of new products. The government also hires scientists of many kinds, both for basic research and for applied work. The Department of Defense, the Department of Agriculture, and the Department of Health, Education and Welfare all hire scientists.

Limitations of science. Some people have come to think of science as just a modern form of magic. They expect it to solve all of our problems. Scientists know better. In the first place they know that science is not magic. It is more a matter of careful thinking and hard, patient work. They also know that many important problems cannot be solved by scientific methods.

Scientific methods can only solve questions that have definite answers. "What is the center of the earth made of?" "Why is steel stronger than lead?" "How does a muscle get energy from food to do work?" Questions like these have definite answers, if only we can find them. Scientists are often successful at solving such problems. Anyone may repeat their experiments to see if their discoveries are really correct. It is possible to get nearly everyone to agree on the true answer.

But what about questions without such definite answers? "What is the best form of government?" "What makes a poem great?" "Who is the prettiest girl in school?" "Which religion contains the greatest truth?" These questions do not have such definite answers, do they? Answering them must include a great deal of personal judgment. You may have some very strong feeling about them, but it is hard to prove your beliefs to other people. There are no observations or experiments that will make everyone agree on the answers.

So you can see that science does not claim to answer all questions. Such fields as politics, religion, literature, and art are very important to us, but they are mostly outside the field of science. Science helps us understand the living and nonliving world around us. It even includes the workings of our own bodies. It has been very successful at this, and it continues to make important discoveries.

What can science mean to you? Most scientists are professionals. They have been trained in college. They make their living as scientists. But there are some amateur scientists. Remember, a scientist is anyone who uses scientific methods to learn new facts. This could be you. Some boys and girls your age have built their own telescopes to look at the stars. Others have studied the plants and animals that live in their neighborhoods. Insect study gives amateurs a chance to do good work. There are so many kinds of insects that no one has studied how all of them live, grow, and act.

Even if you never become a scientist, you can learn to think like one. You can learn to see your problems clearly before you try to solve them. You can check all the known facts before you make up your mind. You can try different ways of solving a problem to see what works best, as a scientist does when he experiments. You can learn to accept new ideas and give up old ones when new facts make this necessary. This approach is part of what is called the scientific attitude. If you develop a scientific attitude toward your life problems, your study of science will be worthwhile.

Fig. 1-4. Doctors and nurses must use a great deal of biological knowledge in their work. Are scientific methods used in making new medical discoveries? How? (Elizabeth Wilcox, Riverdale, N.Y.)

Fig. 1-5. Many people enjoy studying living things out-of-doors. Are you one of these people? (Don Sturkey)

The most important thing science has done is to teach us to look at the world as it is. We no longer believe in ghosts and witches. When we look at a rock we do not fear that an evil spirit lives in it. When we get sick we do not call in a witch doctor to cure us with magic. Our ancestors did all of these things. Science has helped us to see that there are natural causes for the things that happen. It has shown us how to find these causes and how to do something about them.

What is biology? As we have said, biology is the branch of science that deals with living things. Biologists have learned a great deal about plants and animals, how they live, how their bodies work, and how they affect one another. The whole field of medicine is really just a special branch of biology. The control of disease is one of the great victories of modern biology. A better understanding of biology will help you to take good care of your body.

Biology has helped to improve farming. Better breeds of farm animals and food plants have been produced. Better ways of fertilizing crops have been developed. A good farmer must understand biology. Even the home gardener can make good use of biological knowledge.

Conservation is another field in which biology plays an important role. Soil, water, forests, and wildlife can

be destroyed if we are not careful. Biologists learn how to use these resources wisely.

Nature study is a pleasant hobby for many people. Perhaps you have gone out on hikes or camping trips. Perhaps you enjoy hunting or fishing. You will enjoy them more if you know something about the living things around you. Many biologists spend their time finding out how plants and animals live and grow. You can learn about nature study from biology books; not just textbooks like this one, but also from many kinds of field guides and nature study handbooks.

We are happy that science has produced knowledge and inventions to make our work easier and to give us pleasure. We like the practical, useful things in our modern, scientific world. This book will help you understand some of the useful things that scientists have produced. It will do something else, too. We human beings are curious creatures. We are always asking why things are the way they are. This book will help to satisfy this human need. It will help you to understand yourself, and also to appreciate this wonderful world of which we are all a vital part.

CHECK YOUR FACTS

1. What is a scientist?
2. What is science?
3. Name some types of problems that can be solved by science and some types that science cannot solve.
4. What is an experiment? Why are controls used in experiments?
5. What methods may a scientist use besides experiments?
6. What are some scientific attitudes that we can use in everyday life?
7. Where do scientists work? Where might you find scientists at work nearest to your school?
8. What is studied in each of the following fields of science: astronomy, geology, physics, chemistry, biology?
9. Make a list of ways in which science has affected our lives.

CHAPTER 2

The Living Substance

How can you tell when things are alive? They usually have a pretty definite size and shape, but this is not enough to prove they are alive. A statue has definite size and shape! Movement often helps us to tell that things are alive. Animals move a great deal. Even plants move somewhat. Their leaves turn toward the light, and materials flow inside them.

Life activities. Movement is just one of the many activities that living things carry on. These life activities are what make living things different from all nonliving things. ***Response*** is another life activity. If a cat sees a mouse, the cat jumps at the mouse. If a potted plant is in a window, the plant grows toward the light. If you see a car coming toward you, you get out of the way. These are examples of responses. This ability of living things to respond to their surroundings helps them to avoid danger and to get the things they need. It helps them to survive.

Each kind of living thing has some way of reproducing. No one animal or plant can live forever. The ability of living things to reproduce has made it possible for life to continue on the earth for billions of years. ***Reproduction***, then, is another life activity.

Four other important life activities are carried on inside the living substance. These are ***nutrition***, ***respiration***, ***growth***, and ***excretion***. Nutrition is simply the using of food. All living things use food.

One use for food is to supply energy. When living things break down food to release energy, the process is called *respiration*. There are several forms of respiration, but in the most common one oxygen is needed. The oxygen unites with the food to release energy. You breathe in order to get oxygen from the air. This makes it possible for you to carry on respiration.

Another use for food is in growth. When living things grow they build food up into more and more complicated materials until it becomes a part of their own living substance.

During the processes of respiration and growth there are usually things left over which the body does not need. These waste materials are gotten rid of in several ways in different living things. Getting rid of wastes is called *excretion*.

The process of being alive is simply a matter of carrying on these life

activities. Each kind of living thing must be able to respond to its surroundings, reproduce its kind, get food, grow, and get rid of waste materials. It takes energy to do all of these things. This makes respiration an especially important life activity. Without respiration we could not use the energy in foods that we eat.

It is well to remember that there is no single "right" way to list these life activities. We have listed seven of them. Some biologists add others. Some lump them together to get a shorter list. The important thing to remember is that living things carry on a number of activities which help them to survive. This is what makes them different from nonliving things.

What are living things made of? If living things are so different from things that are not alive, they must be made of something very special. The living material in a plant or animal is called ***protoplasm*** (*proh*-toh-plasm). The activity of this protoplasm gives living things the ability to do the things you have just read about. You are alive, so you must be made of protoplasm.

Suppose we were to get several samples of protoplasm to examine. We would find that it really is not much to look at. Protoplasm is not completely liquid or completely solid, but a sort of jelly-like substance. It may be colored but usually it is clear and almost colorless. It feels slippery. It often looks and feels like raw egg white.

All plants and animals contain protoplasm. This is one way in which living things are alike. Do not think that protoplasm is always exactly the same, or that it always looks the same

Fig. 2–1. How many life activities are represented in this picture? Name each one. (Lynwood Chace)

when you see it under the microscope. Even protoplasm from different parts of the same body may be different.

We have said that you are made of protoplasm. If you are just a big lump of this slippery, gooey stuff, what keeps you from oozing off your chair? How do you hold your shape? To answer this, think first about air. There is nothing softer than a mass of air. A sheet of rubber is not very firm either. If rubber is wrapped around air in the right way we have a basketball. If you have ever been hit in the head by a basketball you know that it feels quite solid.

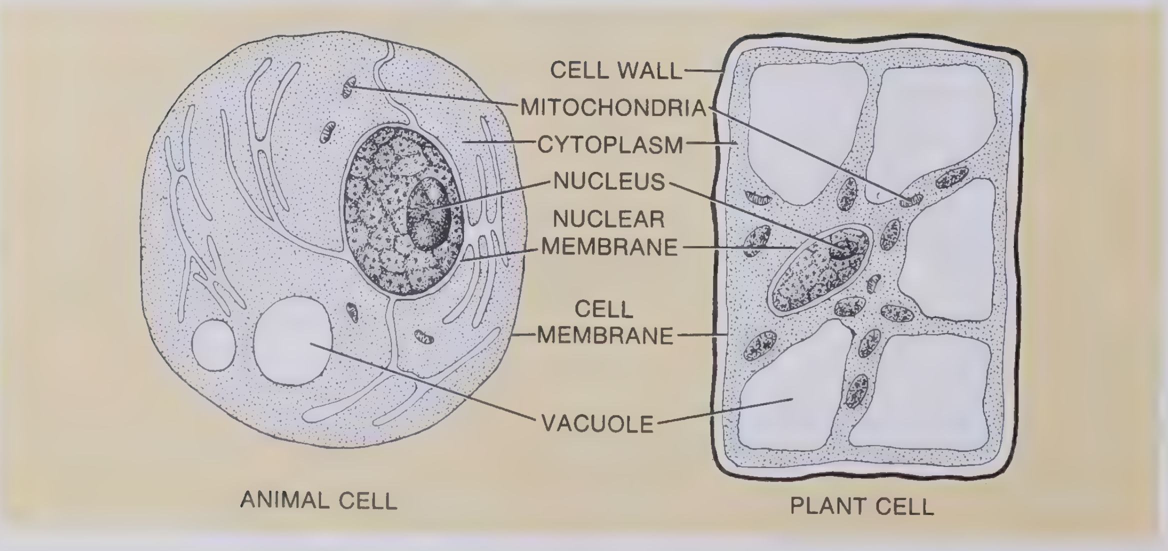
In much the same way protoplasm comes wrapped in small packages. Each package has enough pressure inside its cover to give some firmness. So you are not just a large lump of protoplasm. You are a large mass of little lumps, all fastened together. Another reason why you hold your shape is that you contain quite a bit of strong, nonliving material. This solid material adds strength and form to your body. Mineral matter in your bones and tough fibers in your skin are examples of this.

Cells—units of protoplasm. The little packages of protoplasm we have been talking about are called ***cells.*** Protoplasm is usually organized in the form of cells. Living things are made up of cells. You can see some cells without a microscope, but most of them are much too small for that. The smallest cells are about 1/250,000 of an inch across.

Some living things are made up of just one cell. Others are made up of many cells growing together. Your body contains trillions of cells. One droplet of your blood the size of a pinhead contains millions of living cells, with room in between them for liquid.

Look at Figure 2–2. It shows two cells. Remember, as you look at these drawings, that cells have thickness. They are not flat as they seem to be

Fig. 2–2. A typical animal cell (left) and a typical plant cell (right). What similarities and differences are present?



in the drawing. One cell is a type you might find in an animal. The other is a type of plant cell. As you see, there is not much difference. The important parts of a cell are the same in all living things.

There is a round object inside which is called the ***nucleus*** (*noo*-klee-us) plural ***nuclei*** (*noo*-klee-eye). This is a very important part of the cell because it controls most of the cell's activities. We shall learn more about the nucleus later on.

You can see in Figure 2–2 that the main mass of the cell is the ***cytoplasm*** (sy-toh-plasm). In most cells cytoplasm is clear and colorless, but some cells have colored cytoplasm. Often it looks quite smooth, but in other cells it has a grainy appearance. Much of the cell's work takes place in the cytoplasm.

There are many special structures in the cytoplasm to do special jobs. One example of this is the ***mitochondria*** (mite-oh-kon-dree-ah). They are small, oblong objects scattered throughout the cytoplasm. Their job is to carry on the life activity of respiration. In the mitochondria food is broken down and combined with oxygen to produce energy. They are sometimes called the "powerhouses of the cell."

In Chapter 4 you will learn about the production of several kinds of chemical materials in the cell. One is a substance called protein (proh-teen). The cell is made partly of protein. Cytoplasm contains a great many very tiny units called ***ribosomes*** (ribe-o-sohms). Ribosomes manufacture proteins. They are too small to be seen with an ordinary microscope, so they were not discovered until scientists began using electron microscopes (See Figure 2–3).

Still other special structures have been found in the cytoplasm. Research is going on to learn what each of them does. Remember that cytoplasm looks like just so much jelly. It has surprised everyone to learn that it has so much detailed structure.

Most cells have one or more hollow structures in their cytoplasm called ***vacuoles*** (vak-yoo-ohls). You might call these the cell's storage bins. Vacuoles may contain almost any stored material which the cell needs to keep for a while. Water, salts, foods, and waste materials are some of the things which are often stored in vacuoles.

Around the outside of the cell is a very thin layer of material. It is called the ***cell membrane***. The word membrane means a thin sheetlike structure. Other membranes surround the nucleus, the vacuoles, and the mitochondria. The cell membrane separates the living material inside the cell from the nonliving world around it. Anything which enters or leaves the cell must pass through this cell membrane. Things like food or oxygen or carbon dioxide can pass through. Some other materials cannot. It seems to have quite a bit of control over what enters and leaves the cell. You will learn more about how this happens in Chapter 5. We might say that the nucleus is the cell's front office, the cytoplasm is the workshop, and the membrane is the gate keeper.

Plant cells usually produce a layer of strong, dead material around themselves, outside the cell membrane. This structure is called the ***cell wall***, and it gives strength and protection to the cell. Wood is merely a mass of old, empty cell walls. They were formed by the cells of the tree when that part of the tree was alive.

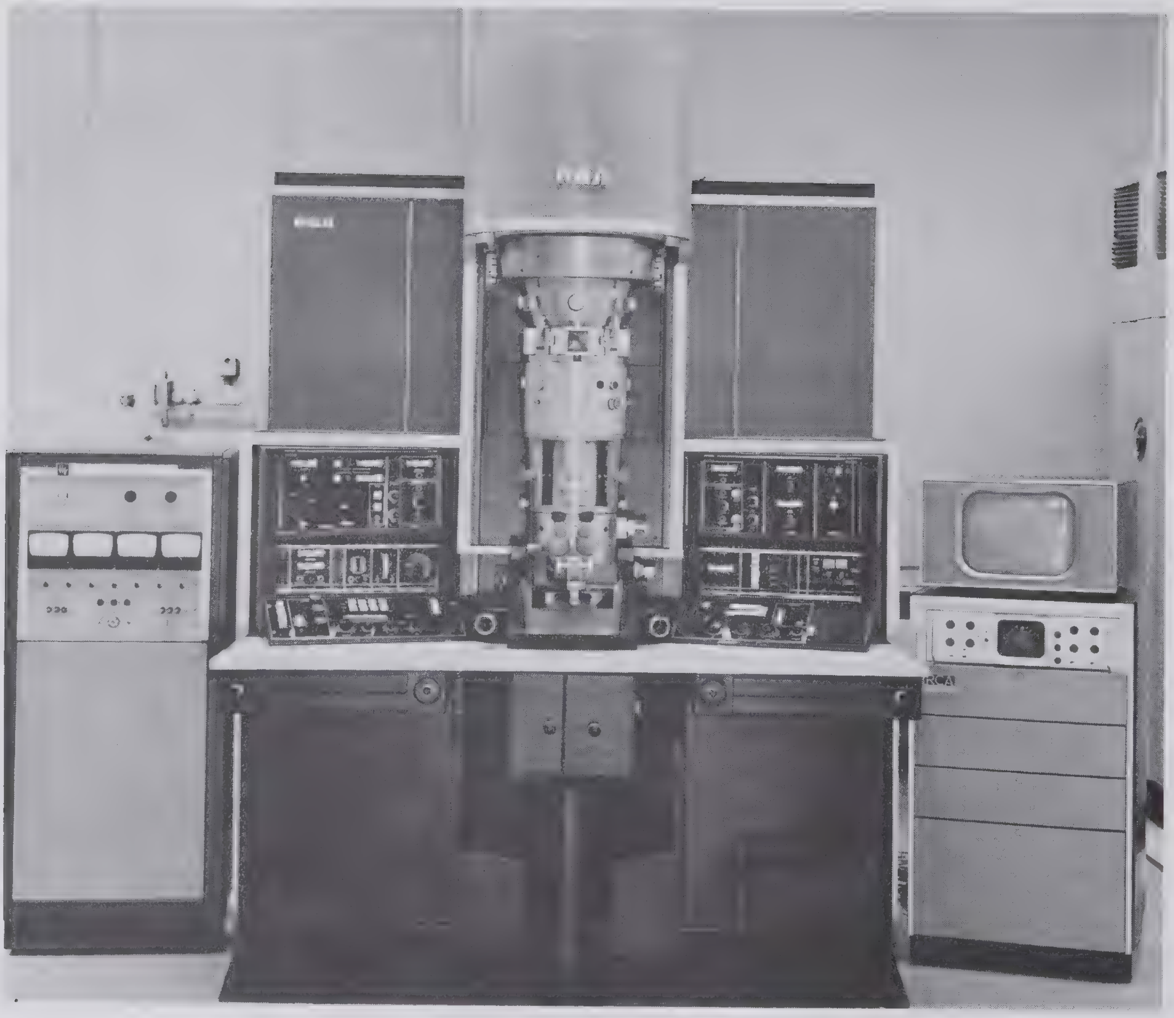


Fig. 2–3. This is an electron microscope. With its aid you can see things much smaller than anything an ordinary microscope will reveal. (RCA photograph)

Animal cells need to be more flexible than plant cells to allow for movement. They do not generally produce stiff, strong cell walls the way plant cells do. Sometimes they are covered by just a cell membrane. Some other animal cells have thin, tough outer coverings for added strength. Still others deposit nonliving materials between the cells to give support to the whole group of cells. The mineral layers between bone cells give bone its strength, just as cell walls give wood its strength.

By this time you are probably wondering where the protoplasm is. It is the living part of the cell. The nucleus, cytoplasm, and the membranes are all protoplasm. Structures like cell walls are not living parts of the cell. Protoplasm is not a single material that is always the same. The term protoplasm is simply a handy word for all living material. This living

material is really a great many different materials organized to work together. Cells are the organized, working units of protoplasm so the study of protoplasm must always include the study of cells.

The life activities which we mentioned earlier in this chapter are activities of protoplasm. They are carried on in cells by chemical action. You will need to know some chemistry to understand them. The next chapter will give you some of this simple chemical knowledge.

ACTIVITY

Using the microscope. Before you try to use a microscope study Figure 2–4 and learn the names of its parts. This will help you to understand directions when your teacher tells you how to use it. Your microscope may look a bit different from the one in the picture, but it will have about the same parts. It may have an electric light instead of a mirror. Follow all directions very carefully. A microscope is an expensive instrument. It must be handled with care.

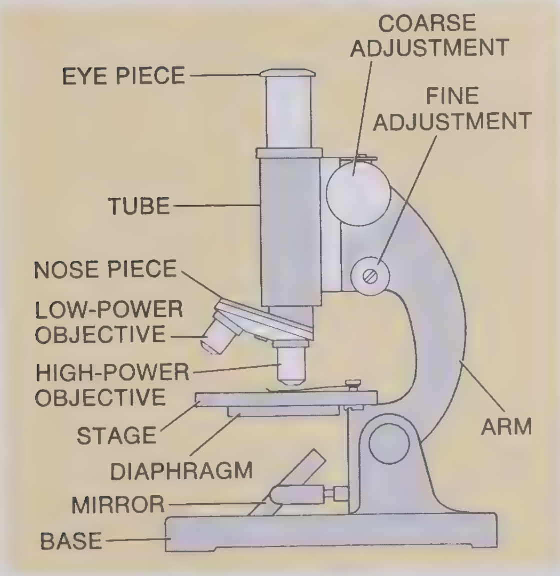
1. **Carrying.** Always carry a microscope in an upright position. Otherwise the eyepiece may fall out. Use a firm grip on the arm to carry it. If necessary place your other hand under the base. Do not set the microscope on the corner of a table where it may get knocked off.

2. **Mounting.** Only very small objects can be viewed under the microscope. Most school microscopes give magnification of 100 times in low power and 430 times in high power. This is too much magnification for looking at fingers, pencils, or insects. For such work you need a lower power, such as you might get from a good magnifying lens.

Objects viewed under the microscope must be placed on a small piece of glass called a ***microscope slide,*** and they are nearly always covered with a still smaller piece called a cover glass. At times your teacher may have you look at prepared slides. In these the object which is to be studied has been permanently mounted on the slide with the cover glass cemented over the top.

Often you will use temporary

Fig. 2–4. The parts of the ordinary laboratory microscope.



mounts. You simply place the object in a drop of water on the slide and cover it with a cover glass. These are also known as wet mounts because water is used. In the activity on page 19 wet mounts are used for viewing the onion and cheek cells. When you place a cover glass on the drop of water lower it slowly from the side like closing a trap door. This gives the air a chance to escape, and there will not be so many bubbles caught under the cover glass.

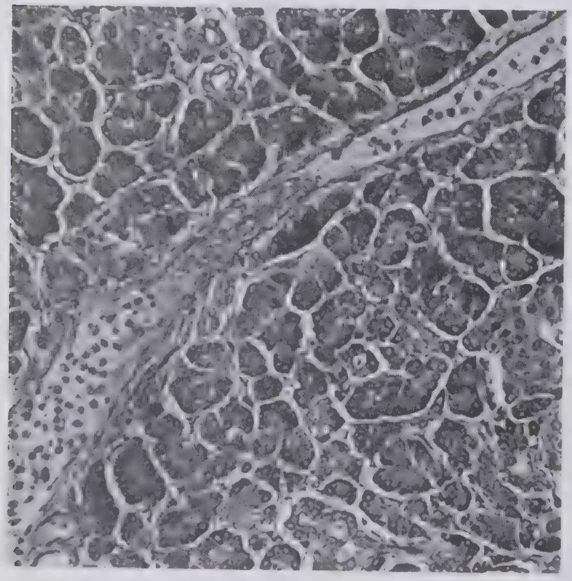
3. **Focusing.** When your slide is ready, place it on the stage of the microscope. The part you wish to see should be centered over the hole in the middle of the stage. Swing the nosepiece around so that the low power objective is in line with the tube. (This is the shorter objective.) Look through the eyepiece and adjust the mirror so that it reflects light up through the microscope.

Next, move your head to one side so that you can see the objective. Turn the coarse adjustment wheel until the low power objective nearly touches the cover glass. Then look through the eyepiece and slowly raise the objective until the object on the slide comes into focus. You may have to move the slide to get the exact view you wish to see. Only a small part of the slide can be seen at once, and moving the slide will enable you to see all parts of it. What do you notice about the direction of this movement as seen through the microscope? The fine adjustment wheel is useful for getting things into perfect focus. Practice using it.

If the object is very small you may wish to see it under high power. First focus in low power, as before. Then swing the nosepiece around to bring the high power objective into line (it is the longer one). Only a small turn of the fine adjustment will then be needed to bring the object into focus. Be very careful. The high power objective is close to the cover glass, and too much adjustment can break something.

4. **Problems.** In general you will find that low power is much easier to use than high. It is easier to focus under low power, and it is much easier to get enough light.

Fig. 2–5. The cells of a plant, highly magnified. Note how many cells are fastened together to make up the whole mass of plant tissue. How many parts of the cell can you see? Name them. (Eric Greve.)



Use low power whenever you can. Save the high power for things that are too small to see otherwise.

If the view through the microscope looks foggy there are two possible causes. One of these is dirty lenses. Never clean a microscope lens with a handkerchief. Use special ***lens paper.*** It is soft and very clean. It has no dirt in it to scratch the lenses. Breathe on the lens to moisten it. Then rub it with lens paper. Do this to the top eyepiece lens and to the bottom objective lens. Once you have laid the piece of lens paper down, do not use it again. Why?

Another cause of a foggy view is too much light. The diaphragm can be turned to shut out some of this light. Often this gives a clearer view of the object, even if it is not as bright.

As soon as you finish observing a temporary mount clean your slide and cover glass. Wash them in water and dry them with a cloth or a cleansing tissue. Lens paper is not necessary for drying slides, and it would be too expensive to use all the time for this purpose.

It will probably take a little time for you to get used to your microscope but practice will soon enable you to become quite proficient in handling it.

ACTIVITY

Observing cells. 1. Cut out a small piece from one layer of an onion. From its inner surface you can peel off a very thin sheet of material which is actually a single layer of cells. Sometimes this sheet of cells stays on the outer surface of the next layer of the onion instead of coming off with the layer which you have removed. Place the sheet of onion cells in a drop of water on a glass slide. Can you see the cell walls? Cytoplasm? Nuclei? If the nuclei do not show very well try staining the cells with iodine solution. The nuclei will stain a dark yellow-brown, and then they will be easier to see. Your teacher may ask you to make a drawing of what you see. Biologists often make drawings to record their observations.

2. Use your fingernail or a toothpick to gently scrape a little moisture from the inside of your cheek. Place this material on a microscope slide, stain it with iodine solution, and cover it with a cover glass. Cells are always coming loose from the lining of your mouth, and you should be able to see them under the microscope. Do they have cell walls, like the onion cells? Can you see the nuclei?

CHECK YOUR FACTS

1. **Explain what is meant by each of the seven life activities discussed in this chapter.**
2. **Is there any nonliving thing that carries on all of these seven**

activities? Is there any that carries on some of them? How about an automobile? Explain your answer.
3. What is protoplasm? What does it look and feel like?
4. Name six parts of a cell and tell what each of them does.
5. Describe two differences between plant and animal cells.

CHAPTER 3

Some Simple Chemistry

Chemistry is the study of matter. Matter is any sort of material or substance. It is anything that takes up space and has weight. If you look around you, you will see that there are thousands of different kinds of matter in the world.

One of the greatest discoveries chemists have made is that there are only a limited number of really basic materials. These are called ***elements***. There are 90 natural elements in the world, but only about 35 of them are common. A few more have been artificially produced by atomic scientists. All of the thousands of materials around us are made up of these basic substances, the elements.

Two common elements. Oxygen is an element. It is a gas that looks and feels like air. In fact, the air is about one-fifth oxygen. Another common element is hydrogen. Like oxygen, it also is a gas and has no color, taste, or odor. It is very light in weight. A balloon full of hydrogen will float in air.

If we were to mix oxygen and hydrogen together, nothing would happen. We would just have a mixture of oxygen and hydrogen. But if we were to touch a lighted match to this mixture, something would happen. There would be an explosion. The oxygen and hydrogen would react chemically with one another to produce a new material —water. Because of the heat from the explosion this water would not be a liquid. It would be in the gas, or vapor form. If we could cool this water vapor it would become ordinary liquid water. So we see that it is possible for elements to unite with each other to form some new material. In this case the new material is water.

Compounds are made up of elements. Water is not an element. Water is a ***compound***. When two or more elements unite to form a new substance, we call that substance a compound. Most of the common materials around you are compounds. You are made up of compounds.

A compound always contains two or more elements united in a very definite way. Water, for instance, is made of two parts of hydrogen for every one part of oxygen. We often write this in a kind of shorthand as H_2O. The H stands for hydrogen. The O stands for oxygen. The number 2 shows there are two units of hydrogen for one unit of oxygen.

Notice that water is entirely differ-

$O_2 + 2H_2 \rightarrow 2H_2O$

Fig. 3–1. The formation of water. The larger circles represent oxygen atoms. The smaller ones are hydrogen atoms. See how the letters below tell the same story. How many molecules of each material are shown?

ent from either oxygen or hydrogen. It is not a gas at ordinary temperatures. It will not burn like hydrogen. It will not make things burn like oxygen. It has its own characteristics, or properties. This is true of all compounds. Each has its own properties, which are entirely different from the elements that are in them.

Another common compound is carbon dioxide. This is the gas that bubbles out of soda pop when you shake the bottle. We also breathe it out from our lungs. Its formula is CO_2. This means that one unit of the element carbon (C) is united with two units of oxygen (O_2). You already know what oxygen is. You have seen carbon, also. It is usually a black solid material. Soot and charcoal are fairly pure examples of carbon. Notice here, again, that the compound is different from either of the elements which combine to make it. Carbon dioxide looks like oxygen but it does not act like it. It will put out a fire. Oxygen makes fires burn harder. Carbon dioxide certainly does not look like dirty, black carbon, yet it contains carbon.

Fig. 3–2. The formation of carbon dioxide during the burning of carbon. How many atoms are there in each molecule? What holds them together?

$C + O_2 \rightarrow CO_2$

So far we have mentioned three elements. Some others which you may have heard of are nitrogen (the main gas in air), sulphur, iron, copper, phosphorus, silver, gold, aluminum, calcium, chlorine, and sodium. Most of these are never found naturally in the pure, element form. They are nearly always united to form the many kinds of compounds that make up the world around us.

The structure of matter. Another important discovery of modern chemistry is the fact that matter is made of definite small particles. Such a particle is called an ***atom.*** Each element has a different kind of atom. There are 92 natural elements because there are 92 natural kinds of atoms.

Hydrogen atoms are the lightest of all. Uranium has the heaviest atoms. Each element has its own particular characteristics because each has its own kind of atom. When elements unite to form compounds, it is atoms that do the uniting.

A particle which is formed by two or more atoms joined together is called a ***molecule.*** Such a molecule is the smallest unit in a compound. The atoms in a molecule are held together by a force called a ***chemical bond.*** Some kinds of atoms have an attraction for each other. They form chemical bonds which form the molecules. Other elements have no attraction for one another. They cannot combine to form compounds. The ability of two elements to form chemical bonds de-

pends on the structure of their particular atoms. Some molecules contain only two atoms. Some contain several atoms. Other molecules contain thousands of atoms. These giant molecules are especially important in the forming of protoplasm.

Some elements are usually found in the form of molecules. Oxygen atoms, for instance, are generally in pairs. Two oxygen atoms are held together by chemical bonds. This pair of oxygen atoms is an oxygen molecule. Its symbol is O_2.

The smallest unit of water is made up of two hydrogen atoms united with one oxygen atom. This is a molecule of water. Remember that its symbol is H_2O. The molecule of a compound is always made up of at least two kinds of atoms which are held together by their chemical bonds. Sometimes several different elements combine to form a compound.

Chemical changes. When oxygen and hydrogen unite to form water, one molecule of oxygen unites with two molecules of hydrogen to form two molecules of water (Fig. 3–1). We write the reaction this way:

$$O_2 + 2H_2 \longrightarrow 2H_2O$$

The arrow means that a chemical change has taken place. The chemical nature of the material is no longer the same. ***Energy*** is required to produce some chemical changes. This energy is the ability to do work. Other chemical changes result in the release of energy. Energy is stored in the bonds that hold atoms together. When these bonds are broken, energy is released.

There is more energy stored in molecules of hydrogen and oxygen than there is in the molecules of water that form when hydrogen and oxygen combine. This energy is released when the water molecules are produced, as they are whenever any hydrogen gas burns. When this gas burns, oxygen in air unites with the hydrogen to form water molecules. The water molecules appear as water vapor. While the hydrogen is burning, light and heat are given off. Light and heat are the forms of energy that are released when hydrogen burns. This burning is a chemical change.

Another example of a chemical change is the burning of charcoal. Charcoal is made of carbon. One atom of carbon (C) unites with one molecule of oxygen (O_2) to produce one molecule of carbon dioxide (CO_2). This reaction is shown in Figure 3–2 and in the following equation:

$$C + O_2 \longrightarrow CO_2$$

Carbon and hydrogen are in all of our common fuels – wood, coal, oil, and gas. When oxygen unites with them, carbon dioxide and water vapor are formed. Our foods also contain carbon and hydrogen. Oxygen unites with them in our bodies, producing carbon dioxide and water.

In the chemical changes we have mentioned so far, oxygen united with some other material. This process is called ***oxidation*** (ocks-suh-*day*-shun). Oxidation is one very common type of chemical change, but there are many others. One important thing to know about chemical changes is that they always either use up or release energy.

The need for energy. Energy exists in several forms such as electricity, light,

heat, and the energy of motion. The energy which is used to form or to break chemical bonds is called chemical energy. Energy is easily changed from one form to another. For instance, the chemical energy stored in coal molecules becomes heat when the coal is burned. This heat energy can be used to make the steam that drives steam engines and generators. It has been changed to energy of motion. Generators change the energy of motion into electricity. What forms of energy can you think of that are produced by electricity?

In somewhat the same way the chemical energy stored in food molecules can be changed to do the work of the living cell. You can see evidence of this in your own body. Your body is warm. This heat is a form of energy. You can move. The chemical energy which was stored in your food has been changed to form heat and the energy of motion.

Energy is necessary for activity of any kind. Few of us realize that without energy life could not possibly continue. Even the smallest plants and animals require energy for their cells to function properly. Even though the cells are not moving, energy is still being used in their other life activities.

ACTIVITY

Formation of compounds. Place a short candle in the bottom of a jar or large beaker. Light the candle. Place a lid or glass plate tightly over the top of the jar until the candle goes out. Lift the lid just long enough to pour in a little limewater. Then hold the lid shut while you shake the jar enough to swish the limewater around inside. What change do you notice in the appearance of the limewater?

Now set a burning candle on the table top. Hold a cold surface just above the flame for a moment. A jar containing cold water will work very well (do not hold the jar low enough in the flame to deposit black soot on it). Notice the film of moisture which collects on the glass.

When limewater turns milky white it indicates that carbon dioxide is present. Did your limewater turn white? Where did the moisture which formed on the cold glass come from? Remember that oxygen is present both in carbon dioxide and in water. Candle wax is made entirely of carbon and hydrogen. Where did the oxygen come from?

CHECK YOUR FACTS

1. **In your own words explain what is meant by the following terms: matter, element, compound, atom, molecule, chemical change, energy.**
2. **Name some common elements.**
3. **Name some common compounds.**
4. **How are molecules related to compounds?**
5. **Describe some common examples of chemical changes.**

6. **In the examples you have been given are the compounds anything like the elements they are made of? Explain your answer.**
7. **Describe some cases in which we get useful energy from chemical changes.**

CHAPTER 4

The Chemistry of Protoplasm

Living things, like everything else, are made up of elements—the same elements that exist in the common nonliving things around us. Suppose you weigh 120 pounds. Then your body consists of about 78 pounds of oxygen, 22 pounds of carbon, 12 pounds of hydrogen, three pounds of nitrogen, and two pounds of calcium. There are nearly 20 other elements in your body but all together they make up only about three pounds of your body weight.

The table below shows the elements found in protoplasm in the largest amounts.

The Most Common Elements in Protoplasm

Element	Symbol
Oxygen	O
Carbon	C
Hydrogen	H
Nitrogen	N
Phosphorus	P
Sulphur	S
Potassium	K
Magnesium	Mg
Calcium	Ca
Iron	Fe
Sodium	Na
Chlorine	Cl
Iodine	I

The thing that makes living matter so special is not the elements it contains. It is the way in which these elements are joined together. The elements are combined in a very complicated group of compounds. The finest machines we have ever built are so much simpler than a living cell that there is no comparison. There is still a great deal to be discovered about the workings of protoplasm, but many of the main facts are now known. New discoveries are being made almost every day.

The composition of protoplasm. In the rest of this chapter we shall explain a little about the composition of protoplasm. Some names of chemical compounds will be used again later in the book. Your teacher will tell you which names you should remember.

Some Compounds Found in Protoplasm

Water	80%
Proteins	12%
Fats	3%
Carbohydrates, nucleic acids, vitamins, and other compounds	3%
Mineral salts	2%

The table on page 26 shows the main compounds in a more or less typical sample of protoplasm. As you see, there is more water than anything else.

Carbohydrates (kar-boh-*hy*-drayts) are the basic food substances of the cell. All carbohydrates contain carbon, hydrogen, and oxygen. They come in several forms, such as starches and sugars. One form can be changed to another rather easily. The particular form of carbohydrate we are most interested in right now is the simple sugar called ***glucose*** (*gloo*-kose). The formula for glucose is $C_6H_{12}O_6$. Glucose is manufactured in green plants by a special process which we shall study later on. Both plants and animals need glucose as food, but animals cannot make it themselves and must get it from plants or other animals.

The energy of the cell. Protoplasm, as we have said, does its work by chemical action. We have also said that the power to carry on this work comes from chemical energy. The most important material which supplies this chemical energy to cells is glucose. Glucose is broken down in the process of respiration.

If sugar were simply burned up, it would give off heat, but this heat could not be used to do the cell's work. Respiration releases the energy of the sugar molecule in a different way. The cell takes apart the glucose molecule one step at a time. The glucose molecule has six carbon atoms in it. During respiration it is changed to one kind of molecule after another until it ends up as molecules with only one carbon atom in them. These are carbon dioxide molecules (CO_2).

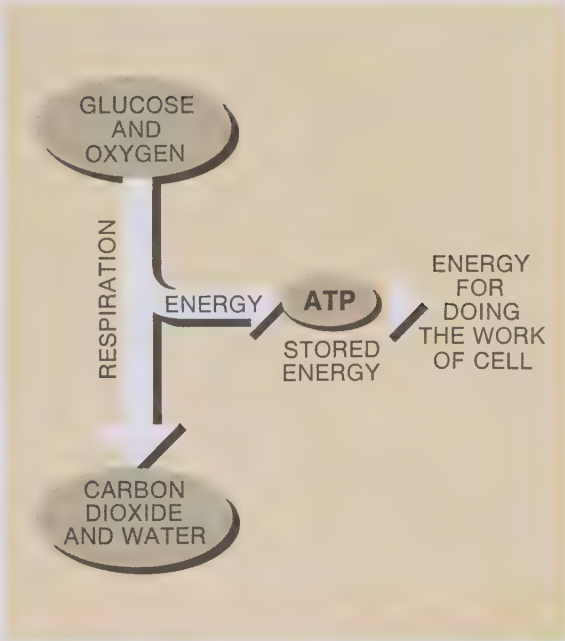


Fig. 4–1. Diagram of respiration. Respiration releases energy to do the work of the cell. ATP is the carrier of this energy. The sugar is broken down into carbon dioxide and water.

Each time one of these materials is changed into another, energy is released. This energy is not allowed to escape as heat. Instead, the energy is used to build up a special phosphorus compound called by its initials ***ATP.*** (Its real name is adenosine triphosphate, but even the scientists generally call it by its initials for convenience.) Later the energy stored in the ATP can be used whenever it is needed to do the work of the cell. Think of ATP as the energy carrier of the cell. The carbon and hydrogen in the glucose are eliminated by combining them with oxygen. This means that the final products of glucose respiration are carbon dioxide and water. Water is needed in the cell, but carbon dioxide is a waste and must be excreted.

Some cells do not use oxygen at all. They simply break down the sugar part of the way and get only part of the energy from it. Yeast cells can do this, as you shall find out when you study Chapter 22.

Not all carbohydrates are used to supply energy. Some are used as building materials. Cell walls of plants are made of a carbohydrate. This is what gives plant structures like wood their strength.

Building new compounds. Some compounds formed during the break down of glucose are used by the cell as building materials. They are the starting point for making such compounds as fats, proteins, and nucleic acids.

Fats are made of carbon, hydrogen, and a little oxygen. They are used by the cell in building parts of the cell's membranes—not only the cell membrane but also the ones covering the nucleus, vacuoles, and mitochondria. They are also used as a reserve energy supply. Fat is stored in some vacuoles. Later it is broken down by respiration to release energy. The solid fats are most common in animal cells. The liquid oils are more common in plants.

When cells build new materials the simple compounds formed during glucose breakdown are first built up into fairly large molecules called ***fatty acids.*** Then these are put together to make the still bigger fat molecules. Energy needed for this building up process is supplied by ATP.

Proteins are very important compounds in the cell. Their molecules often contain thousands of atoms. Besides oxygen, carbon, and hydrogen, proteins always contain nitrogen. Still other elements are sometimes present also.

There are millions of proteins in the world. Your own body contains many thousands. Yet all of these different kinds of protein molecules are formed from a limited number of fairly simple compounds called ***amino acids.*** There are about twenty of these. Chemical bonds can easily form to fasten animo acids together. A protein molecule is simply a large number of amino acid molecules which are stuck together in this way. Again, it is ATP which supplies the energy to do this work.

The amino acids themselves are formed by adding nitrogen to simple fatty acids. Plants can get this nitrogen from simple mineral salts. Animals cannot do this. They must get their nitrogen from compounds already produced by plants. In fact, animals get most of their amino acids ready-made from proteins in the foods they eat. Man, for instance, can make some of the amino acids he needs. He must get the others from his food.

Another use of amino acids is the building of ATP and ***nucleic*** (noo-*klee*-ic) ***acids.*** To do this, phosphorus must be added. Nucleic acids are used in the nucleus to control the cell's activities. You will learn more about this in later chapters. You already know what ATP does.

Functions of proteins. Some proteins are used to form parts of living things. The cell's membranes are made of two layers of protein molecules with a double layer of fat molecules between them. Animals produce tough protein fibers between the cells to bind their bodies together. Leather is strong because it contains large amounts of such protein fibers. Fingernails and hair are made of protein.

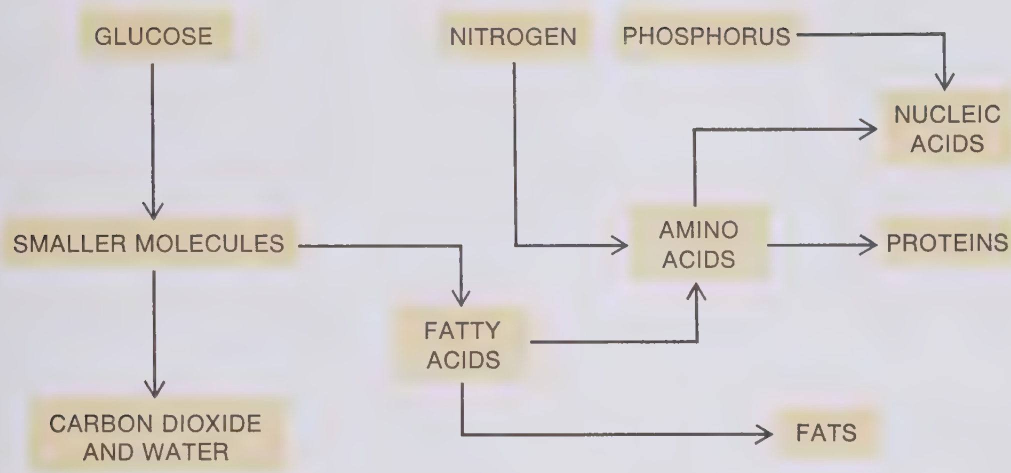


Fig. 4–2. Some of the compounds formed in the cell. What supplies the energy used by the cell to do this work?

The use of proteins for building purposes is important, but most of the proteins in cells have a more important use. They control the chemical changes which take place in the cell. These proteins which control chemical activity are called ***enzymes.*** Each enzyme is a different kind of protein molecule. Each controls one particular chemical change in some other material. Each step in the breakdown of glucose is controlled by a different enzyme. This is why mitochondria are able to carry on respiration. They contain the enzymes needed to do this job. Each step in the buildup of new compounds is controlled by a particular enzyme. It takes several thousands of different enzymes to carry on all of the different chemical activities which are going on in your cells right now. We might say that cytoplasm is a workshop in which enzymes are the experts who direct the cell's work.

Summarizing the chemistry of protoplasm. Several other kinds of compounds are found in cells. We shall not try to describe them all at this time. If you have a general picture of the sort of activities going on in the living substance, that is enough for now. Let us sum up very briefly what we have said about protoplasm:

1. Protoplasm is made up of ordinary elements. The most important are carbon, oxygen, hydrogen, and nitrogen.
2. These elements are combined to form many kinds of compounds. including water, carbohydrates, fats, nucleic acids, and proteins. The most abundant compound is water.
3. Carbohydrates, and especially glucose, furnish both energy and building materials for the making of other compounds, such as fats and proteins.
4. Energy from the breakdown of glucose is stored in ATP molecules.
5. The energy for building fats, proteins, and other compounds is supplied by ATP.
6. Each separate step in the buildup

and the breakdown of all these compounds in the cell is controlled by special proteins called enzymes.

7. When carbohydrates, fats, or proteins are broken down to release energy, their carbon and hydrogen are combined with oxygen, forming carbon dioxide and water.

In the next chapter, we shall learn how plant and animal cells get the food materials they need in order to carry on these various chemical processes.

ACTIVITY

Energy from chemical change. Fill a small test tube about one-third full of water. Mount a large peanut on the end of a pin and place it under the test tube (the pin can be pushed up through a slice of cork to make it stand up). Light the peanut and let it burn with the flame under the end of the test tube. Use a thermometer to take the temperature of the water in the test tube before and after burning the peanut. Did the water warm up? Can you get it to boil? It takes energy to heat water. Where did this energy come from? Which life activity releases energy in somewhat the same way? Could your body obtain energy from a peanut? What other substances could you use to obtain this energy?

CHECK YOUR FACTS

1. **What are some common elements found in protoplasm?**
2. **If protoplasm is made of ordinary elements what makes it different from nonliving materials?**
3. **What are the most common compounds in protoplasm?**
4. **What are two important uses for glucose in the cell?**
5. **What does ATP do in the cell?**
6. **What is oxygen used for during respiration? Is it always used this way?**
7. **What compounds are used in the building of fat and protein molecules?**
8. **Where does the energy come from for building new compounds in protoplasm?**
9. **What are enzymes? What do they do?**

CHAPTER 5

Food for Hungry Protoplasm

If you read the last chapter carefully you noticed that the cell must have glucose. It needs glucose for energy, and it must have materials from glucose to build some compounds in its protoplasm. Where does this glucose come from? We said it is made in cells of green plants. This food-making process is the most important manufacturing process on earth. It is called ***photosynthesis*** (foh-toh-*sin*-theh-sis).

To carry on photosynthesis, the plant must have four things. These are water, carbon dioxide, sunlight, and ***chlorophyll*** (*klor*-oh-fil). Chlorophyll is the green material in plants.

Green plants make glucose. Glucose is made in the cells of green plants from carbon dioxide and water. The formula for glucose is $C_6H_{12}O_6$. This means that it contains carbon, hydrogen, and oxygen. Water (H_2O) is made of hydrogen and oxygen. Carbon dioxide (CO_2) is made of carbon and oxygen. So water and carbon dioxide have all the elements needed to make glucose. However, water and carbon dioxide contain too much oxygen. The cell must get rid of some of it.

Photosynthesis is really a whole series of chemical changes. The first of these changes depend directly upon light to make them happen, so they are often grouped together and called the ***light phase*** of photosynthesis. Energy from ATP is used to carry on the later steps in food making. Since light is not used, these are called the ***dark phase.*** This does not really take place in the dark, but comes right after the light phase during daylight.

During the light phase light is absorbed by the chlorophyll molecules and changed into chemical energy. This energy is used to produce ATP and to break down water molecules. The ATP is used to power the chemical changes which take place during the dark phase. The breakdown of water molecules produces hydrogen and oxygen. The oxygen escapes and the hydrogen is used in the dark phase.

In the chemical changes of the dark phase this hydrogen is combined with carbon dioxide to make food. Carbon dioxide has too much oxygen in its molecules, so half of this oxygen is combined with some of the hydrogen to form water. Then the rest of the hydrogen combines with the remaining carbon and oxygen of the carbon dioxide to form glucose.

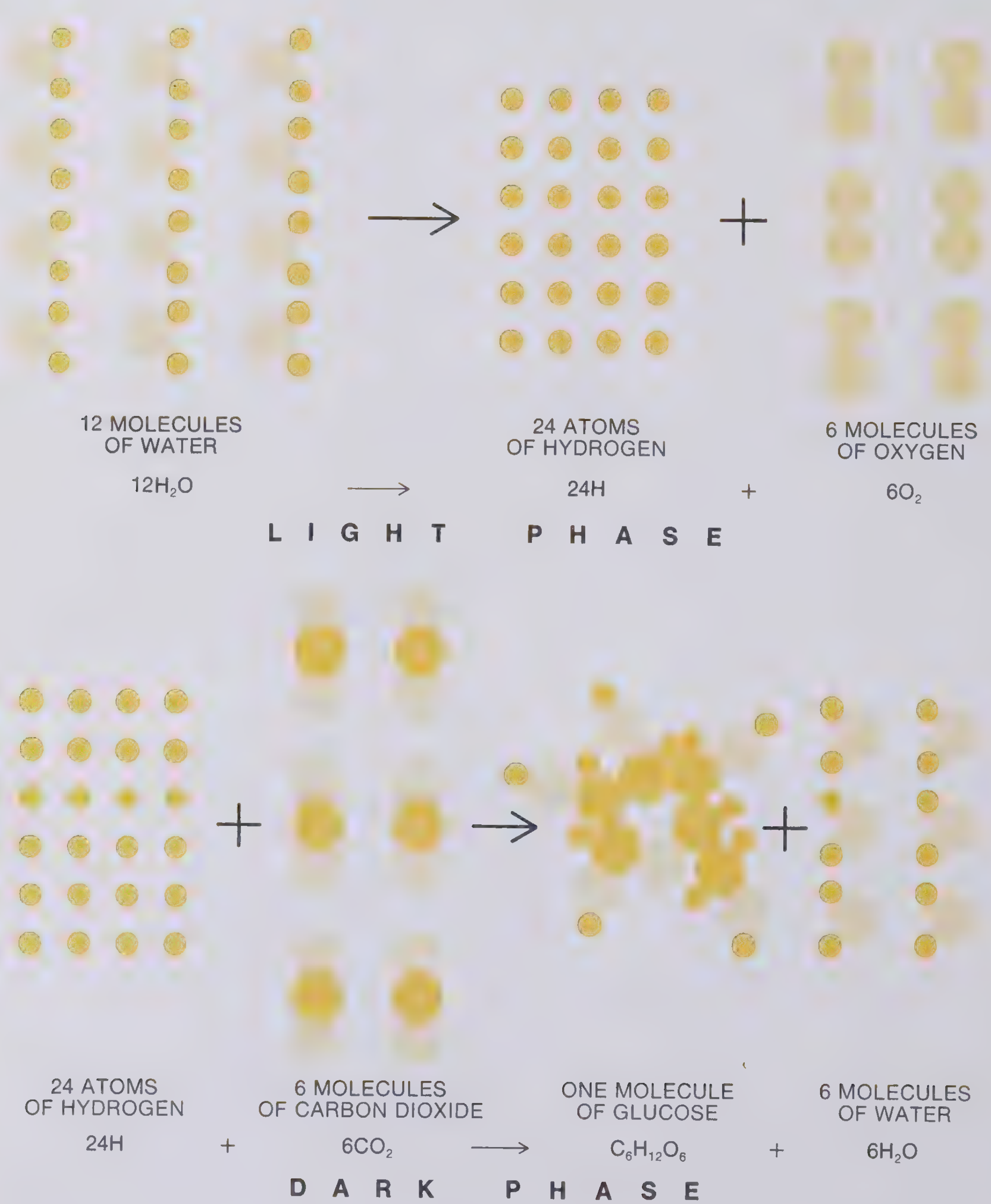


Fig. 5–1. A simple diagram of the two main stages in photosynthesis. First, water is split. The oxygen escapes. Then the hydrogen combines with carbon dioxide to form food. What supplies the energy for each of these sets of changes?

Remember that all this takes place in a series of chemical changes. ATP supplies the energy needed to bring about each of these changes.

Perhaps this explanation of photosynthesis has you a bit mixed up. Do not let this disturb you. Just try to understand the main idea. We can sum it up this way:

1. Photosynthesis is a food-making process.
2. It takes place in green plants.
3. The food is made from carbon dioxide and water.
4. Oxygen is left over and passes off into the air.
5. The most common food produced is glucose.
6. Energy for photosynthesis comes from sunlight.
7. This light energy is absorbed and put to work by chlorophyll, the green material in the plant.

If we wish to sum up the process in a single chemical equation we can do it this way:

$$12H_2O + 6CO_2 \longrightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Actually, the ATP formed during photosynthesis may be used to produce other compounds, such as fats or plant oils and proteins. ATP is also found in animal cells.

Photosynthesis versus respiration. You will notice that photosynthesis is just the opposite of respiration. Photosynthesis builds up glucose. Respiration tears it down. Photosynthesis uses energy. Respiration supplies energy. Photosynthesis uses carbon dioxide and produces oxygen. Respiration uses oxygen and produces carbon dioxide (Fig. 5–2, page 34).

How does photosynthesis help the plant? Photosynthesis gives the plant a supply of glucose for its cells. Remember that glucose supplies both energy and building materials. You can think of glucose as a sort of storage battery for the cell. Energy stored in the glucose molecules can be used by the cell whenever it is needed.

Notice that a green plant carries on both photosynthesis and respiration. Photosynthesis must make enough glucose to keep the plant supplied all the time. Extra glucose is often stored in plants by changing it into starch. It may also be changed into other kinds of sugar. Common table sugar is formed by combining two simple sugars like glucose. Glucose, table sugar, and starch are all examples of carbohydrates.

Animals depend on plants for food. Animals, including man, cannot make glucose. They must get it from green plants. Animals carry on respiration, but not photosynthesis. During respiration both animals and plants give off carbon dioxide. This carbon dioxide goes into the air. From the air, land plants get the carbon dioxide needed to make glucose. You can see that the same carbon atoms that are now part of you have been used many times before. You are made of second-hand materials! The carbon dioxide you are breathing out right now will be used by plants to make food again and will become part of other living things. Atoms which are now part of you have, in the past, been part of other people, fish, dinosaurs, trees, seaweeds, and all other kinds of plants and animals.

There is something else to notice about photosynthesis. Not only does

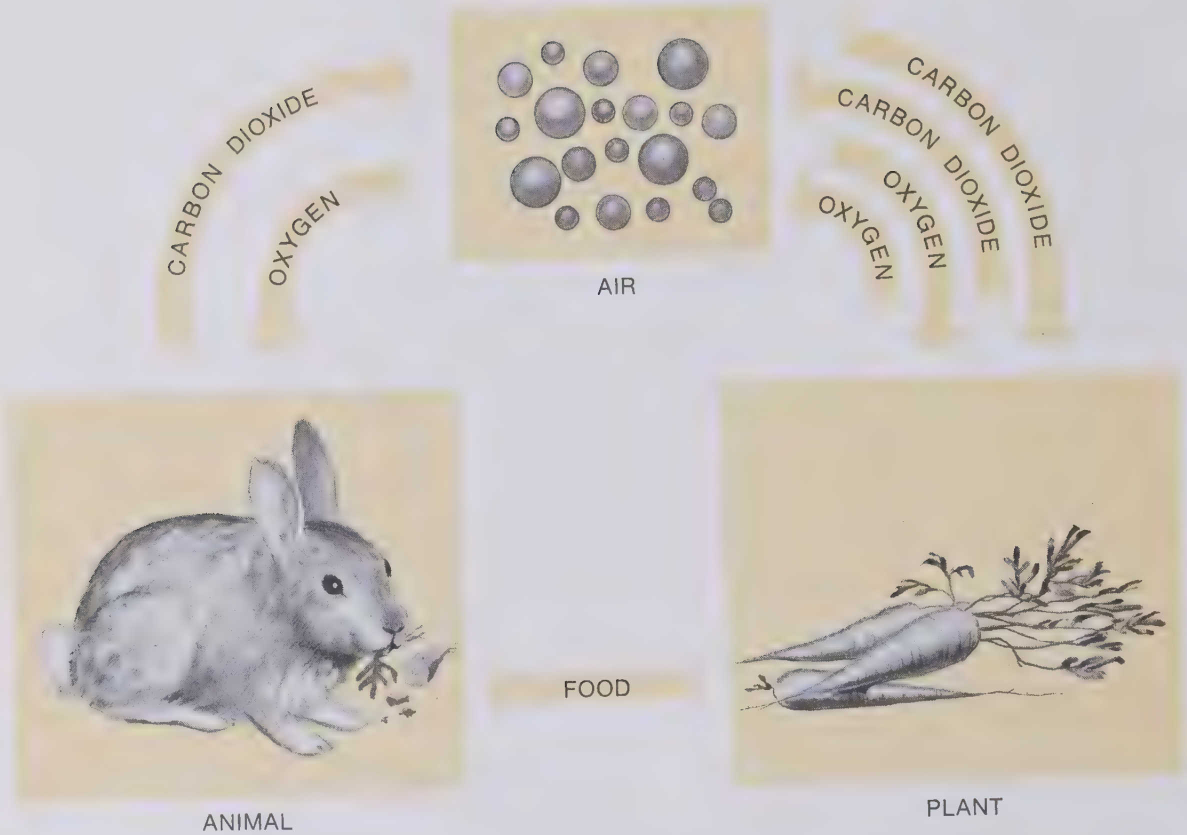


Fig. 5–2. The relationship between air, plants, and animals. Notice that plants carry on both respiration and photosynthesis. What do animals do? Would the plant roots be more or less like the animal than the plant leaves are?

it supply the food used by all living things; it also supplies the oxygen of the air. Respiration keeps using up this oxygen, but photosynthesis puts it right back again. The food you eat and the oxygen you breathe are both supplied by the green plants!

Green plants need mineral salts. As you know by now, green plants not only make glucose; they make all the compounds needed by their cells. They build up plant oils, proteins, chlorophyll, vitamins, and many other substances. To do this they need a supply of many different elements. We have seen how carbon, hydrogen, and oxygen are supplied by water and carbon dioxide. The other elements are usually supplied by simple compounds, called ***mineral salts.*** These mineral salts are commonly found dissolved in water. Soil water supplies minerals to land plants. Dissolved mineral salts are absorbed by water plants directly from the water they live in. Nitrogen, for instance, often comes to plants in the form of mineral salts called ***nitrates*** *(ny-*trates*)*. Nitrogen is used in making proteins, ATP, and several other compounds. Salts called ***phosphates*** *(foss-*fates*)* often supply the

phosphorus needed for making ATP, nucleic acids, and other materials.

Animals have some of this same ability to use simple compounds for building their protoplasm. You get some useful elements like iron and calcium from salts in the water you drink. But animals cannot build all of the compounds needed in their protoplasm. There are many materials which they must get ready-made in the food they eat. Beside glucose these include several amino acids and a long list of vitamins.

How do materials enter and leave the cell? By now you know of several things which must get in and out of cells. These include foods, oxygen, carbon dioxide, water, several kinds of wastes, and several kinds of mineral salts. Every cell is completely surrounded by a cell membrane, so how can anything enter or leave? The answer varies in different cases.

Most materials must be dissolved before they can enter a cell. You have seen things dissolve. When you stir sugar or salt into water, it disappears. You know it is still there because you can taste it in the water. When something dissolves like this, its molecules have separated from one another. The separated molecules become scattered all through the water. It is in this form that most molecules enter a cell.

Molecules in a liquid are always moving. Each molecule shoots along at high speed until it hits another molecule. When two molecules hit each other, they bounce off and keep going.

Cell walls are no problem for the moving molecules. Liquids will pass easily through a cell wall. The cell membrane is the real barrier between the inside of a cell and the outside surroundings. This cell membrane is very thin. It is usually made of only four layers of molecules, but no molecules from the outside could get in if there were no openings in the membrane. Actually there are thought to be tiny holes, or pores, in a cell membrane. They are so small that only things as small as molecules can pass through. Even the larger molecules are too big to enter. The natural motion of small dissolved molecules may send them into the cell through the pores in the membrane.

Chlorella – a simple plant. Now let us picture what happens in a live cell. For an example we shall use a tiny one-celled plant called ***Chlorella*** (klor-el-a). *Chlorella* is one of the many kinds of simple, one-celled plants that live in water. If you cannot find it growing near your school you may study any other one-celled plant. Such a cell carries on all of the life activities, even though it is small and simple.

Figure 5–3 shows what a *Chlorella* cell looks like. This one cell can live all by itself. It is a simple green plant. If there are a great many *Chlorella* cells drifting in a pond all at once, they make the water look green. The green, of course, is chlorophyll. Notice that the chlorophyll is contained in a special structure in the cytoplasm. This is called the *chloroplast* (*klor*-oh-plast). Besides chlorophyll the chloroplast contains the many enzymes needed to control the food-making process. *Chlorella* has one big chloroplast in its cell. Most of our larger plants have many small chloroplasts

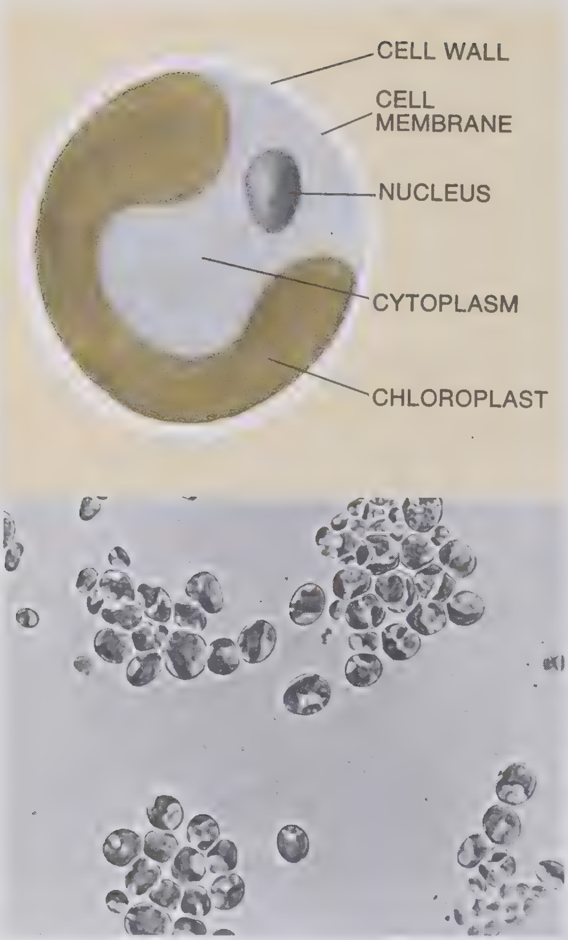


Fig. 5–3. Chlorella, a one-celled plant. (Walter Dawn)

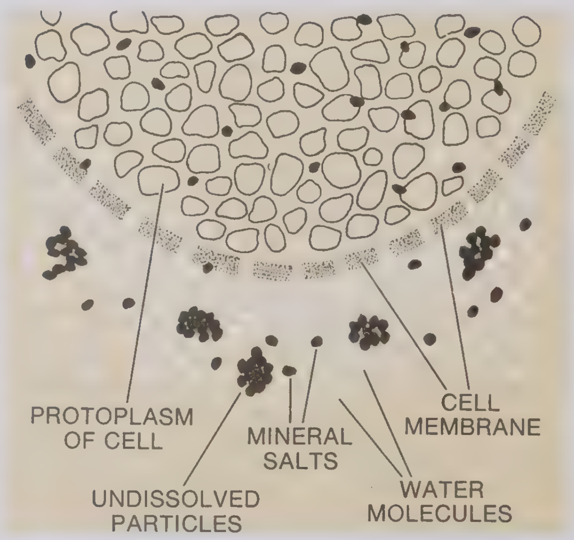
in each cell. Chloroplasts are the food-making units of the cell.

Now look at Figure 5–4. It is an enlarged diagram which shows the conditions at the cell membrane of a *Chlorella*. Notice that the cell membrane has pores in it. Outside the cell is the water of the pond in which the *Chlorella* lives. Inside the membrane are molecules of the living protoplasm. Remember that the molecules are in motion all the time and that they are much smaller than shown in the figure. What happens when a water molecule hits a pore in the membrane? What about the other kinds of molecules?

As you see, some molecules can pass right through the membrane. Others may be too large to get through the pores. Big molecules like those of sugars and fats and proteins stay in the cell. Undissolved particles outside the cell do not enter. Dissolved mineral substances, such as nitrates and phosphates enter and are used by the cell to build up the compounds in its protoplasm. There are water molecules on both sides of the membrane. Water molecules pass both into and out of the cell.

The passage of materials through the membrane does not depend entirely on the chance movements of molecules. The membrane often uses energy from ATP to force materials into or out of the cell. We still do not know how this works, but we do know that it happens. The cell membrane

Fig. 5–4. A diagram of molecules inside and outside a cell membrane. Remember that molecules are in motion. Which ones will get through the membrane?



often selects what does or does not get through. This is very important. It makes it possible for living cells to contain the particular collection of materials needed to carry on the activities of life.

If you watch a living *Chlorella* cell under the microscope you are not able to see anything going on. You simply see a little plant cell in the water. Yet, there is actually a great deal of activity taking place in that simple little plant. Let us picture what this activity is.

Dissolved in the water outside the cell are molecules of oxygen, carbon dioxide, and mineral salts. All of these kinds of molecules enter the cell through the tiny pores in the cell membrane. Sunlight shines on the chloroplast. This gives the chlorophyll the energy to split water molecules and to make ATP. Energy carried in the ATP molecules is used to carry on the cell's activities. Glucose is produced. As it accumulates it is saved for future use by changing it into solid starch grains which are stored in vacuoles. Some food may be changed into plant oils and also stored. Proteins, vitamins, chlorophyll, nucleic acids, and many other useful materials are being manufactured. The cell is growing. Night comes, and photosynthesis stops because there is no more sunlight. Now the cell gets its energy by using the glucose and other foods it made during the daytime. Respiration breaks them down, forming ATP. Energy carried in the ATP molecules is used to manufacture proteins, vitamins, and other useful materials in the cytoplasm. The cell goes on growing. Both night and day the cell membrane uses energy to carry on its work of absorbing needed molecules from the pond water.

Molecules of waste produced by the cell pass out through the cell membrane. In the daytime, photosynthesis is going on more rapidly than respiration, so that oxygen leaves the cell as a waste. At night, when photosynthesis is not taking place, oxygen enters the cell to be used in respiration, and carbon dioxide leaves as a waste.

Different ways of getting food. Notice that this little *Chlorella* plant does not need any materials from other living things. It makes its own food and builds its protoplasm entirely from simple compounds found in the water where it lives. Any living thing that can do this can be called a ***producer.*** Plants with chlorophyll are producers. Animals, including man, must take in food materials which have already been manufactured by other living things. We call animals ***consumers.*** Some plants are also consumers. For instance, a mushroom has no chlorophyll. It must get its food ready-made from decaying wood or dead leaves.

Large plants such as trees carry on photosynthesis. They are made of many cells, but the same processes go on in them that go on in the simple little *Chlorella*. These large plants carry on most of their photosynthesis in their leaves. We shall study these plants in Unit 5.

Materials must pass in and out through the membranes of all cells. It does not matter whether they are plant cells or animal cells. It does not matter if they are single cells or if they come in groups. All living cells absorb the molecules they need through

their cell membranes. All of them get rid of waste molecules through their cell membranes.

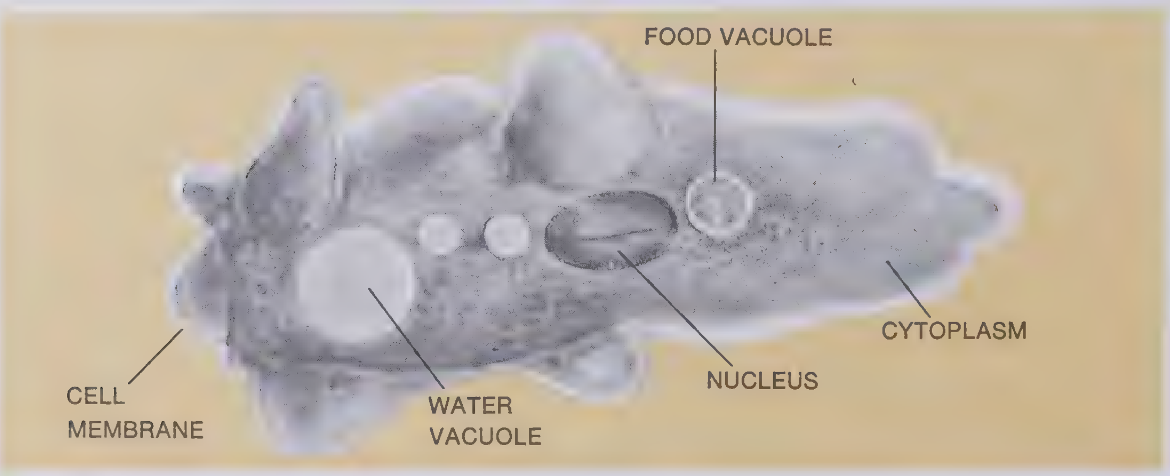
Animals do not make foods. *Chlorella* is an example of a plant cell in action. An example of an animal type of cell is *Ameba* (uh-*mee*-bah). Like *Chlorella*, an *Ameba* is a single cell, but it has no chlorophyll so it cannot make foods. Figure 5–5 shows what an *Ameba* looks like. The shape of the cell changes. There is no cell wall to hold it in a definite form. The almost colorless cytoplasm is surrounded only by a thin cell membrane. A nucleus and vacuoles are present.

Since an *Ameba* cannot make food, it must find food that is already made. The *Ameba* cell is able to move by a flowing motion of its protoplasm. The cell bulges out on one side, and then the rest of the protoplasm flows into the bulge. It looks about like a blob of clear jelly flowing downhill. If it bumps into a piece of food, an *Ameba* simply flows around it on all sides. Finally the food is completely surrounded by the *Ameba's* cytoplasm. There, inside the *Ameba*, the food is slowly digested. The food might be any small piece of dead material in the water, or it might be an entire one-celled plant or animal. It could be a *Chlorella* cell, as shown in Figure 5–6.

In the process of digestion an *Ameba* uses enzymes to change the solid food into simpler, dissolved forms, such as glucose and amino acids. These can be used to supply energy through respiration or to build protoplasm. There may be parts of the food particle that cannot be digested. For instance, an *Ameba* cannot digest the cell wall of a *Chlorella* plant. The *Ameba* simply forces this undigested material out through its cell membrane. When the *Ameba* moves on, the waste material is left behind. Dissolved wastes like carbon dioxide pass out through pores in the cell membrane, just as in *Chlorella*. Oxygen and mineral salts enter through the cell membrane.

The ability of an *Ameba* to take in rather large solid particles is found also in certain cells of large animals. Your white blood cells and some liver cells can do this. Most cells cannot.

Fig. 5–5. Ameba, an animal type of cell. (Walter Dawn)



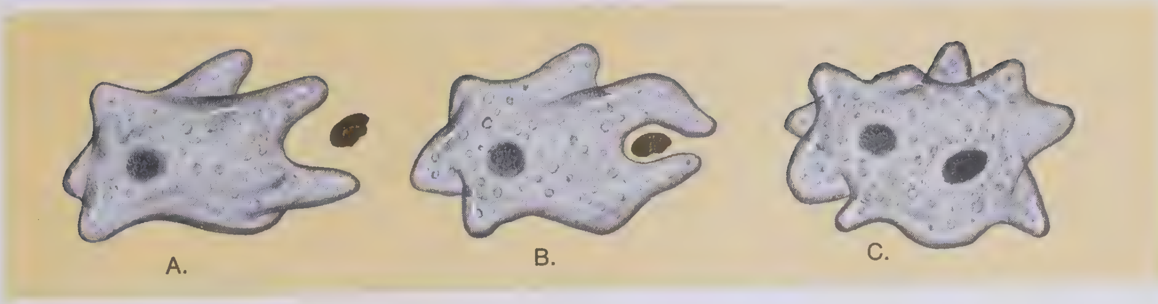


Fig. 5–6. An *Ameba* taking in a *Chlorella* cell.

However, it has recently been found that many animal cells are able to take in tiny particles, which are too big to go through the pores of the cell membrane. These include small undissolved food particles, and also some giant molecules, like protein molecules. A small part of the cell membrane folds out around the particle and draws it into the cell. We do not know yet just how many types of animal cells can do this. Probably plant cells cannot. Their cell walls would be in the way. Certainly the story of how materials pass through cell membranes is not entirely understood as yet.

An *Ameba* and a *Chlorella* cell get their food in different ways, but otherwise they carry on much the same life activities. They absorb dissolved materials through their cell membranes. They use food and oxygen in respiration, and they build new protoplasm.

ACTIVITY

1. **A study of photosynthesis.** Fold a small piece of cardboard over the edge of the leaf of a potted plant. Hold it in place with a paper clip. This will prevent light from hitting that part of the leaf. Leave the plant over night. Next day, when the plant has been in the bright sunlight for several hours pick the leaf and boil it a few minutes in water.

Get a deep pan with about two inches of water in it. Put the leaf in a beaker and cover it with alcohol. Place the beaker in the pan of water. This is what we call a *water bath.* Set the water bath over a Bunsen burner so the flame will heat the water in the pan. The hot water will heat the alcohol which will dissolve the chlorophyll from the leaf. Be very careful because alcohol burns easily.

When most of the chlorophyll has been dissolved out of the leaf, turn off the burner. Note that the alcohol in the beaker has become green. Remove the leaf and rinse it with clear water. Drain off the water and pour iodine solution over the leaf. Iodine is used as a test for starch. If there is any starch in the leaf it will turn dark when the iodine touches it. Remember that starch is the most common form in which carbohydrates are stored by plants.

Do you see any difference in the amount of starch present in the covered and the exposed parts of the leaf? How do you explain this?

2. Your teacher may obtain both *Chlorella* and *Ameba* from a scientific supply company. Observe these cells under the microscope. Can you see all of the things described in this chapter?

CHECK YOUR FACTS

1. What is photosynthesis?
2. In photosynthesis what is the main material produced? What materials is it made from?
3. Where does the energy for the light phase of photosynthesis come from? What material in the plant absorbs this energy?
4. What is a common form of stored food in plants?
5. How do animals differ from the plants? Could they get along without plants?
6. Where do plants get the many elements needed for building protoplasm? Do animals use these same materials?
7. What form must materials usually be in to enter a cell? How do they get in?
8. Describe the activities going on in a *Chlorella* cell. Would these same activities take place in an elm tree or a geranium plant?
9. How are the activities going on in a green plant at night different from those going on in the daytime? During which time is the plant acting more like an animal? Why?
10. What do we mean by producers and consumers in the living world?
11. How does an *Ameba* move? Why is movement more important to animals than to plants?
12. How does an *Ameba* eat?
13. How does an *Ameba* get rid of solid wastes?

CHAPTER 6

Cells in Groups

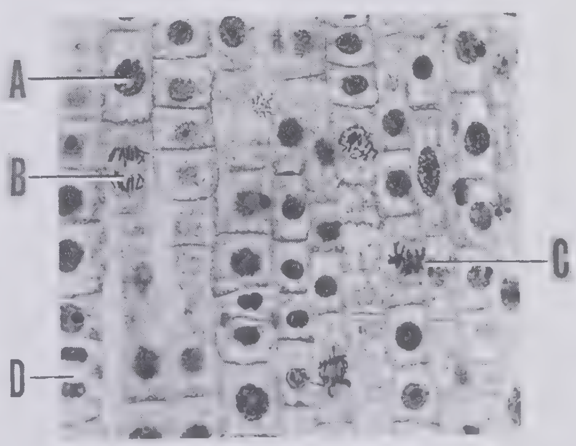
A cell that has reached its full size will either stop growing or it will divide. If it divides, it becomes two cells. When a one-celled living thing divides, the two new cells separate, and become two new individuals. If a cell in a many-celled plant or animal divides, the new cells stay where they are and grow to full size. After a time they divide again. This results in the growth of that plant or animal. You grow in this way too, as more and more cells are added to your body. Cell division also supplies new cells to take the place of worn-out cells.

Inside the nucleus. The process of cell division is not as simple as it sounds. The nucleus begins to divide first. Each new cell must have a nucleus. You will remember that the nucleus controls the cell's activities. It contains many tiny units called ***genes*** (jeens).

Genes in the nucleus control the production of enzymes in the cytoplasm. Think of one gene as controlling the production of one kind of enzyme. Remember that each enzyme controls some chemical activity in the cell. It is the genes, then, that control what a cell can do. The kinds of living things are different from each other because they contain different kinds of genes.

You are human because of the genes in your cells. If you had the kind of genes a hippopotamus has, you would be a hippopotamus. If you had geranium genes, you would be a geranium. You have human genes because you obtained them from your parents. This is what is called ***heredity*** (her-*ed*-uh-tee). Living things inherit a particular collection of genes from their ancestors. In Chapter 10 we shall see

Fig. 6–1. Onion root tip cells under the microscope. They have been stained to make the nuclei show clearly. A. shows a cell about to divide. B. and C. cells are dividing. Notice the chromosomes. D. has just divided. The two new nuclei have formed but no cell wall has been formed between them yet. (Triarch, Inc., George H. Conant, Ripon, Wisconsin 54971)



how genes are handed on in reproduction. We shall see how heredity works. Now, we want to know what happens to the genes when a nucleus divides.

One of the most unusual things about a gene is its ability to reproduce. When a cell is about to divide, the genes duplicate themselves. Each gene becomes two genes. There are then twice as many genes as there were before. Because of this there are enough genes so that each of the two new cells can receive a complete set when cell division takes place.

You may wonder what the genes are made of. It is now known that they mostly are a form of nucleic acid called ***DNA***. (This stands for deoxyribonucleic acid.) No wonder we nearly always use the initials! Other nucleic acids (called ***RNA***) carry "directions" from the genes to the cytoplasm, where enzymes are actually being made. RNA stands for ribonucleic acid.

Nuclear division. There are a great many genes in a nucleus—maybe eight or ten thousand of them. When a nucleus divides, these thousands of genes must be perfectly divided between the two new nuclei. Each new nucleus must get a complete set—one of each kind of gene. How can the cell keep thousands of genes in order and divide them perfectly?

It is possible for the cell to keep its genes in order because it keeps them in packages. Many genes are linked together end to end, sometimes forming long, thin structures. This long string of genes is bound chemically to other materials (protein and RNA) to form parts called ***chromosomes*** (*kroh*-muh-sohms). Think of a chromosome as a package of genes. Different kinds of living things have their genes packaged up into different numbers of chromosomes, but the number is generally the same for any one species. Many bacteria have only one chromosome in each cell. Each cell in your body has 46 chromosomes. A crayfish has over 200.

When chromosomes duplicate, each gene in a chromosome forms another gene like itself. Then when the chromosome splits down the middle, each half has the same genes in it. In this way, two chromosomes and their genes are formed from one old chromosome. The two chromosomes that form from each old chromosome stay together in a pair. When the nucleus divides, one chromosome from each of these pairs goes into each of the two new nuclei.

This kind of nuclear division is called ***mitosis*** (my-*toh*-sis). During mitosis the chromosomes are evenly divided. This means that each of the two cells which forms from the old cell has a complete set of genes. Each of these sets is just like the set that the old cell had. Each of the new cells is able to produce the same enzymes and carry on the same activities as the old cell.

Genes are too small for us to see with a microscope. But we can see the chromosomes if we add stains to them. Even then, the only time we can see them well is during mitosis. At other times, the chromosomes are strung out so long and thin that they do not show clearly. When the nucleus gets ready to divide, the chromosomes coil up. They become much shorter and thicker than usual, and then we can see them. They look like little worm-shaped objects in the nucleus.

Imagine that you are watching the

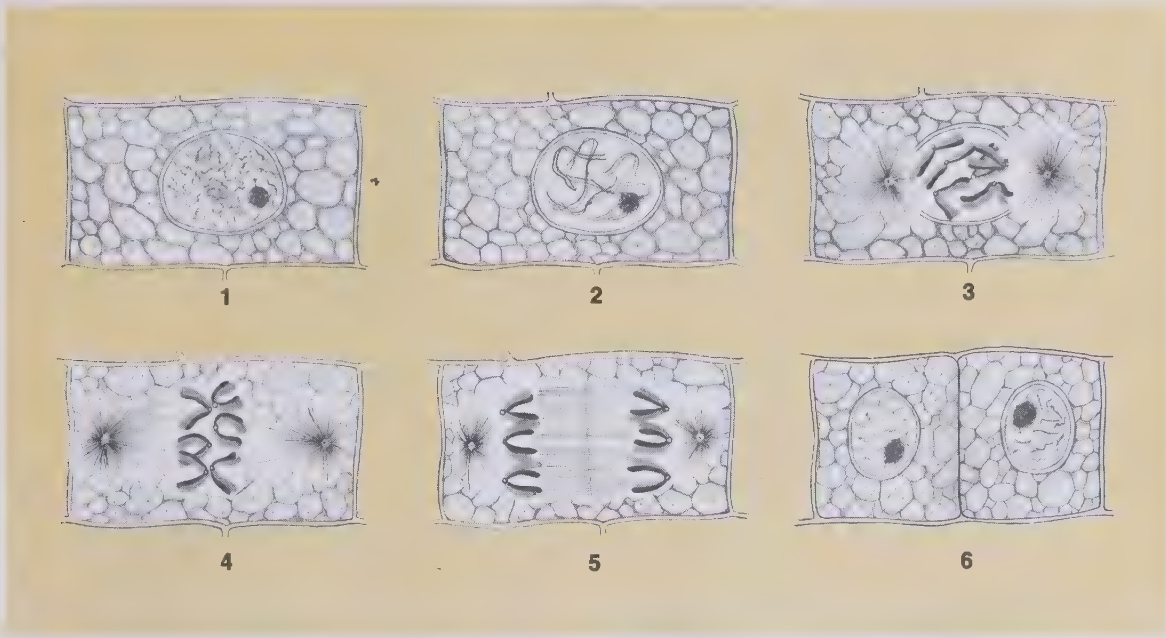


Fig. 6–2. Mitosis in one type of plant cell. 1. a cell is about to begin division; 2. chromosomes appear in the cell nucleus—they are already double; 3. chromosomes become thicker and nuclear membranes start to disappear; 4. chromosomes are lined up and start to separate; 5. two equal groups of chromosomes move to opposite sides of the cell, and two new nuclei are about to form; 6. cytoplasm divides and two new cells are produced as a result of this process.

nucleus of a cell during mitosis. First you see the chromosomes begin to appear. They become shorter and thicker until you can see them easily. If you look closely, you can see that each chromosome is double. We already know why this is so. At this time the membranes around the nucleus begin to disappear. The chromosomes move to the middle of the cell. Now fibers of clear protoplasm form and lead outward from the chromosomes in two opposite directions. Next, the pairs of chromosomes separate and move apart. They move in opposite directions along the clear fibers. All of the chromosome pairs separate at the same time. In this way one of each kind of chromosome reaches one end of the cell, and one of each kind of chromosome reaches the other end of the cell. Each of these groups of chromosomes becomes enclosed by a nuclear membrane. The chromosomes again become long, thin, and tangled together. Finally the chromosomes cannot be seen any more. They have become parts of two new nuclei.

Meanwhile, the cell itself divides. In animal cells, the cell membrane pinches in around the middle. Finally it pinches all the way through, forming two new cells. Each has a nucleus just like the old one. Of course the new cells are only half as big as the old one but they keep taking in food and growing until they are full sized. Then it may be the new cell's turn to

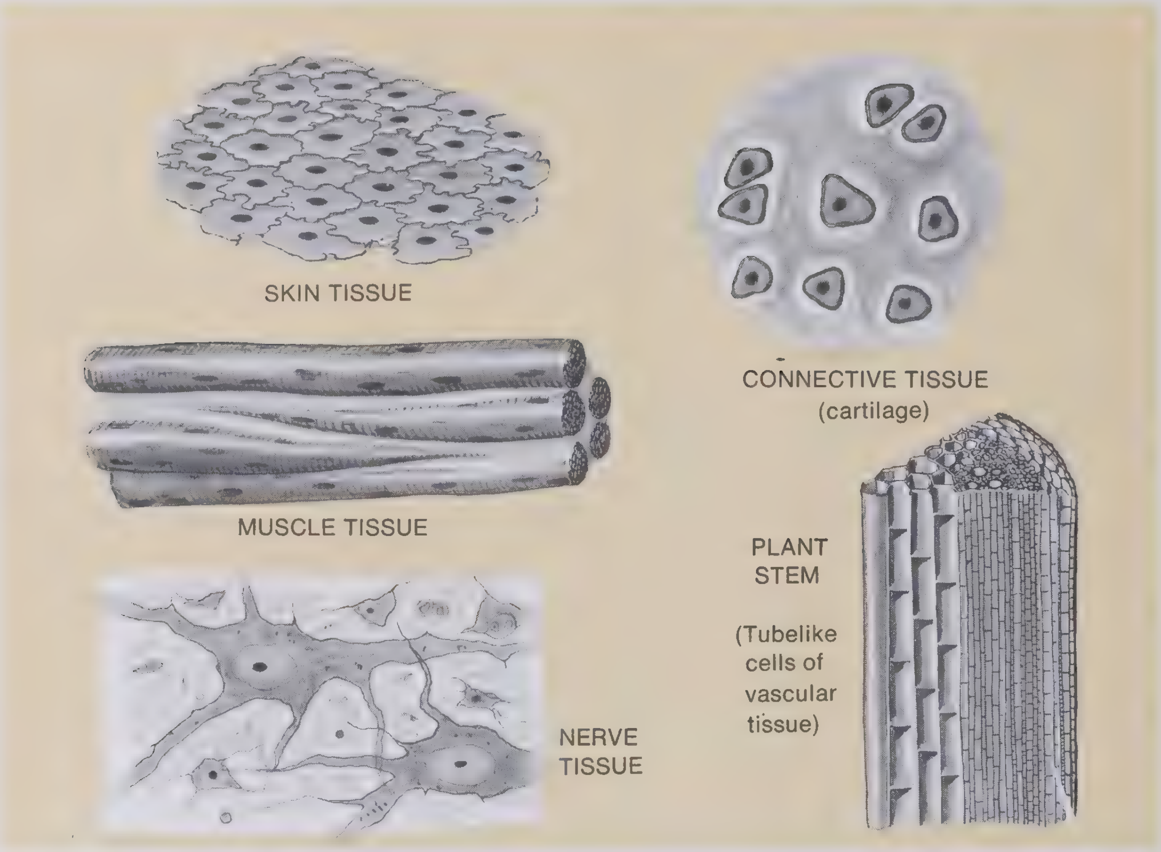


Fig. 6–3. Some of the different types of tissue in plants and man.

divide. Plant cells cannot pinch in two because the cell wall is too stiff. Instead a new wall forms across the middle of the old cell, dividing it into two new cells.

Cells are not all alike. When a living thing is made of many cells, its cells are not all alike. Every living thing starts out as one cell. This original cell divides into two cells. The two divide into four, the four into eight, and so on. As we have said, your body contains many trillions of cells. Since they all come from one cell, they all have the same genes in their nuclei. Mitosis takes care of that. But they do not all develop the same kind of cytoplasm, and they grow into different sizes and shapes. They develop into different kinds of cells which have different jobs to do. The cells in your body are specialists. This is true of the cells in any of the larger plants or animals.

When a cell lives singly, the way the *Chlorella* cell does, it obtains everything it needs from its surroundings. The cell membrane of the *Chlorella* cell is in contact with the water around it. Water, minerals, and oxygen can enter such a cell directly. Wastes can pass out through the membrane into the surrounding water.

Most cells in a man, a fish, or a tree have no contact with the outside sur-

roundings. They are buried thousands of cells deep, with nothing but other cells around them. Such cells need oxygen and food. They cannot get these things for themselves. Cells in larger living things must be organized to help one another obtain the things they need. Each kind of cell has a special job. Of course many similar cells must work together on each job.

Different types of tissues. A group of similar cells that do the same type of work is called a ***tissue.*** There are several kinds of tissue in the human body. One kind forms the *covering tissue* of the body. It includes the outer skin. It also lines the outer part of the mouth and nose. Another type is the *lining tissue.* It forms the linings of all organs inside the body.

Muscle tissue is a third type. Muscle cells are able to contract. They contain fibers that get shorter when they receive energy from ATP. You are able to move because you have muscle tissue.

Another kind of tissue is called *connective tissue.* It forms strong, tough fibers which bind body parts together. Bone is a special kind of connective tissue. It has layers of hard mineral matter deposited between its cells. ***Cartilage*** (*kar*-ti-lij), which we often call gristle, is another special type. It contains scattered cells and a large amount of nonliving material between the cells.

A fifth type of tissue carries messages through the body. This is *nerve tissue.* Nerve cells have long fibers reaching out from the cell body. Your nerves and brain are made of this tissue. Nerve tissue in your brain is learning about nerve tissue right now!

The tissues we have mentioned so far are a few of those found in animals. Plants also have tissues. One important type is called ***vascular*** (*vas*-kyoo-lur) ***tissue.*** Vascular tissue is composed of tubelike cells. They carry liquids inside the plant. Water reaches the leaves from the roots by way of the vascular tissues. Plants also contain several other kinds of tissue, including *food-making tissue* and *mechanical tissue.* Mechanical tissue is made of thick-walled, strong cells which hold up the plant or protect it. Bark has a great deal of stiff, hard mechanical tissue in it.

Groups of tissues working together. Several tissues may be combined into a single working unit, called an ***organ.*** Your stomach is a good example of an organ. On the inside it is covered with lining tissue. In its wall are muscle layers, gland cells, blood vessels, and connective tissue. All of these tissues go together to make one organ—a stomach. Lungs, eyes, and ears are also examples of organs.

Often, several organs work together. They form a ***system*** of the body. Your mouth, throat, stomach, small intestine, and large intestine work together in digesting food. These parts make up the digestive system. Most animals that you know have digestive systems.

Body systems. The higher animals have the following systems:

1. *Covering system.* This is the skin. It also includes special structures such as scales, spines, hair, feathers, or hard plates which may form on the body surface.

2. *Digestive system.* This usually includes a tube which leads through the

body. Food enters the mouth and is digested as it passes through the tube. During digestion, enzymes break down the food into simpler substances dissolved in water. The food molecules are then ready to pass through cell membranes. Parts of the tube may be enlarged to form special organs, such as a stomach or gizzard.

3. *Circulatory system.* This is the blood system. Blood moves through the whole body. It absorbs digested food from the intestine. It absorbs oxygen in the lungs. As the blood moves along, it supplies the body cells with food and oxygen. It absorbs wastes given off by the cells. You will see that the body cells exchange molecules with the blood just as a *Chlorella* exchanges molecules with the water it lives in.

4. *Respiratory system.* This is the part of the body that supplies oxygen. The larger water animals usually have some sort of gills. Large land animals have lungs. In both cases, there is an arrangement of thin membranes, with blood inside. Oxygen molecules pass through these membranes into the blood. Carbon dioxide leaves the blood through these same membranes.

5. *Excretory system.* A kidney is an example of an excretory organ. Different animals have different sorts of excretory systems, but they all are arranged so that the body can get rid of its dissolved wastes. These wastes include mineral salts and nitrogen compounds which are left over when proteins break down. Carbon dioxide is another waste, but it passes off through lungs or gills.

6. *Reproductive system.* This is the group of organs that produces new animals. The organs vary in different types of animals. You will learn more about reproduction later.

7. *Nervous system.* This system enables the animal to respond to things around it. Some nerve cells receive sensations. Others control movement. Animals with more complicated nervous systems can do more complicated things.

8. *Gland system.* A gland system produces special chemicals that help control body action. For instance, a chemical produced by a gland in your head is carried by your blood to all cells in the body. This chemical controls the rate at which the cells divide. In other words, it regulates how fast you grow. There are a number of glands, controlling many body activities.

9. *Muscular system.* Muscles are used to move the animal. You walk by using muscles in your legs and back. A fish swims by using muscles that move its fins and tail.

10. *Skeletal system.* A skeleton is any stiffening material that helps support the soft part of the animal's body. In many animal groups the skeleton is a shell covering the body. A jointed skeleton with movable parts is found in only two of the animal groups. One of these groups has the skeleton on the inside, as you do. The other group, including insects, has the skeleton on the outside.

The simple and the complicated. When we talk about "higher" animals or plants, we mean those with complex, highly organized bodies. People, fish, and insects are examples of higher animals. Trees, grasses, and ferns are higher plants. "Lower" animals and plants are the simple ones without

complex body structures. *Chlorella* is an example of a lower plant. Ameba is an example of a lower animal.

The simplest living things have no body systems. Each cell does everything for itself. The highest animals have all the ten systems which we have described. Other groups fall somewhere in between. For instance, some do not need a respiratory system because they can obtain oxygen through their body surfaces. Earthworms do this. Generally, the large animals must have all or most of the systems. Smaller types may get along with only some of them. Can you see what size has to do with it?

The higher plants must also be well organized. But their systems are different from those of animals. You remember that green plants make their own foods. They have special structures for this purpose.

The most complex plants live on land. They have a root system to obtain water and a stem system to hold up the leaves. Their leaves contain tissues used to carry on photosynthesis. Their flowers produce the seeds from which new plants will come. Their vascular tissue carries water and food throughout the roots, stems, and leaves.

As you see, plant systems are not the same as animal systems, but they perform many of the same life activities.

Later in this book we shall study all the main groups of living things. Each group has its own type of body organization.

Growing tissues. As the cells of a higher plant or animal keep dividing, some of them become specialized in one way and some in another. Some become muscle cells. Some become bone cells, and some become part of still other tissues.

When a cell becomes fully developed as part of a special tissue it may never divide again. You have about all the brain cells you will ever have. The cells which multiplied to form your brain have already become specialized as nerve cells. They cannot divide again. Your brain was nearly full sized by the time you were about twelve years old. You may still be adding bone and muscle cells, but when you are mature, these structures will stop growing. Some cells in your body will always be able to divide. Some of these help in healing damaged body parts. Others produce new blood cells when the old ones wear out.

Many plant cells also become mature and never divide again. The cells in vascular tissue do this. There are other parts of some plants that keep growing every year. A tree grows as long as it lives.

In this chapter, we have seen how cells divide. We have seen how they are organized to form the bodies of many-celled plants and many-celled animals. The organization of cells is what makes possible the marvelous variety of different kinds of living things.

ACTIVITY

Observing mitosis. Examine prepared slides of onion root tips under the microscope. Always

handle prepared slides very carefully. They cost much more than the plain slides you use for temporary mounts. These slides have very thin slices of the growing tips of an onion root. The slices have been stained to make the cell parts show up clearly. Root tips grow rapidly so you should be able to find cells which were in the act of dividing when the root was killed. Look for these dividing cells. What do the chromosomes look like? Can you find some cells with the chromosomes just beginning to show? Are there some with the chromosomes in the center of the cell? Do some show a later stage of mitosis? Your teacher may ask you to draw what you see.

CHECK YOUR FACTS

1. **What are genes? What do they do?**
2. **What are chromosomes? What do they look like?**
3. **What do genes and chromosomes do before the cell starts to divide?**
4. **Describe the process of mitosis.**
5. **Why is it necessary to have different kinds of cells in a single living thing?**
6. **What are tissues? Name some plant and animal tissues.**
7. **What are systems? Name some animal and plant systems. What are their functions?**
8. **Name some body cells that will never divide after they are fully developed.**
9. **What is meant by "lower" and "higher" forms of life?**

UNIT 1 SUMMARY

Science is the attempt to investigate and understand our universe. The scientist studies each problem directly by using observations and experiments. He always tries to get proof. Biology is the branch of science which studies living things.

Living things are made of small units called cells. Each cell has three main parts—the cell membrane, cytoplasm, and nucleus. It is the chemical activity taking place in these cells which we call life. These life activities include growth, reproduction, response, nutrition, excretion, and respiration. Respiration releases energy from food in such a way that it can be used to carry on all of the other life activities.

All things are made of a limited number of basic substances called elements, which are composed of tiny particles called atoms. Elements unite chemically to form compounds. Energy is always used or given off when compounds are formed or broken down.

The living substance, protoplasm, is a very complicated organization of compounds, including water, proteins, carbohydrates, fats, nucleic acids, mineral salts, and many others. Energy released during the breakdown of glucose is transferred to ATP molecules which serve as energy carriers for the cell. This energy is used to build up many of the compounds mentioned above, to make movement possible, and to carry on other life activities.

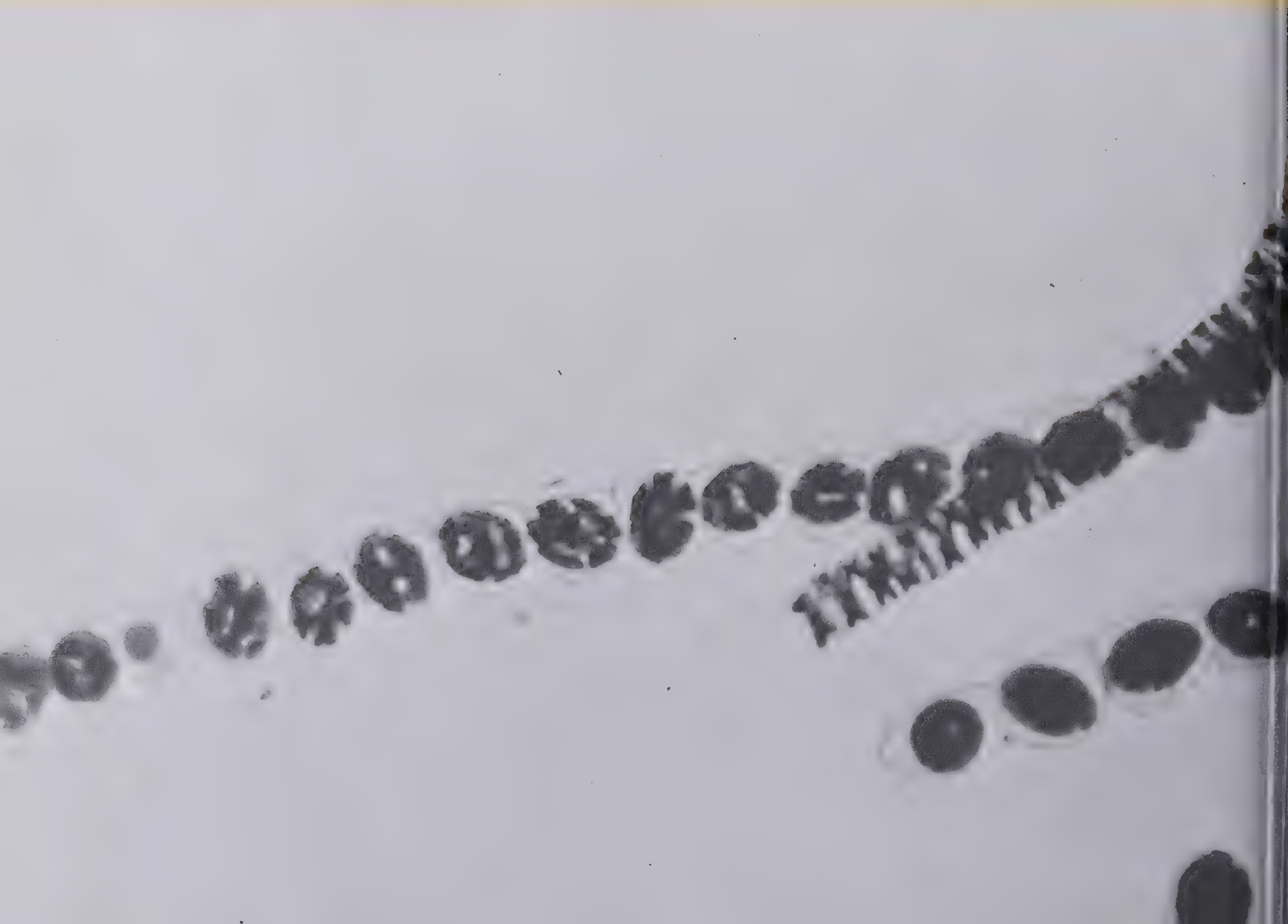
Glucose is produced in green plants by a process called photosynthesis. This glucose is made from carbon dioxide and water. Oxygen and water are left over. The form of energy used to start the photosynthesis process is sunlight. It is absorbed by the green chlorophyll and changed to chemical energy which is stored in the glucose molecule.

When a cell grows to full size it either stops growing or divides. Division provides new cells for growth. It also supplies new cells to take the place of worn-out cells. In the chromosomes of the cell nucleus are the genes. Genes are made of the nucleic acid called DNA. Genes determine what the cell can do. They also are responsible for heredity. When a cell divides by mitosis the chromosomes and genes are duplicated. Each new cell gets a complete set of chromosomes and genes.

Groups of similar cells in plant or animal bodies make up tissues. In the more complex plants and animals tissues are often grouped to form organs. Groups of organs that work together to carry out a general function make up a system.

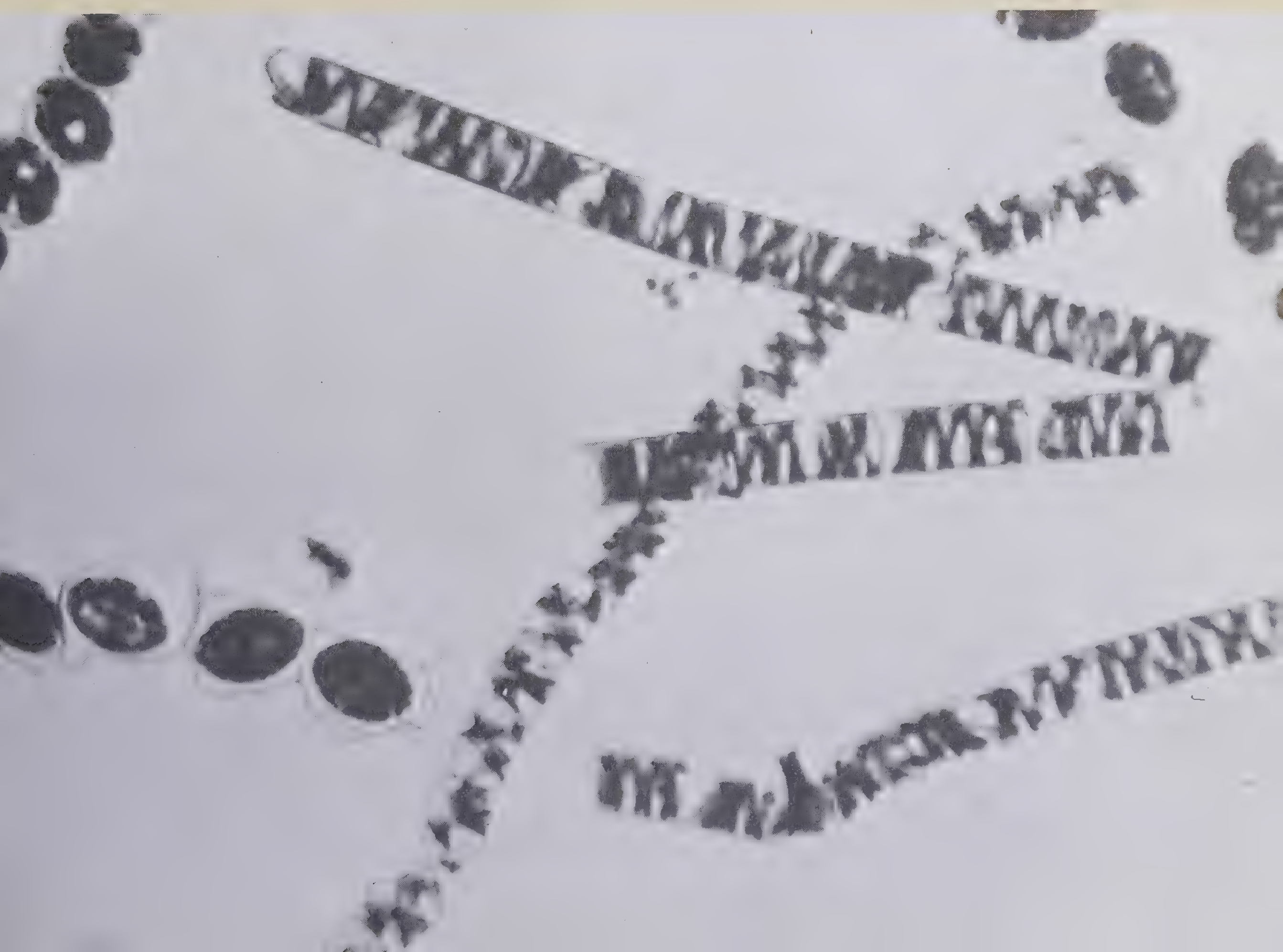
UNIT 2

The Continuation of Life



We live in a world that is very old. Living things came into being over three billion years ago, and life has continued ever since. This continuation of life has been possible because living things have the power to reproduce.

In this unit we shall study the various ways in which reproduction takes place. We shall learn how it is that the young inherit characteristics from their parents. We shall also see how it is possible for the characteristics of a species to change gradually over a long period of time.



CHAPTER
7

Simple Forms of Reproduction

Sooner or later, plants and animals grow old and die. But they generally leave young plants and animals to take their places. If each kind of living thing is to survive, it must have some way to reproduce. In Chapter 6 you learned how cells divide. In plants or animals having many cells in their bodies such division results in growth. The individual becomes bigger as the cells multiply. When a one-celled living thing divides, something quite different happens. The two cells produced by the division separate. Each of them becomes a new individual. This is a simple form of reproduction. More one-celled plants or animals are formed. Each pair of new cells is just like the parent cells because mitosis gives them the same genes. Many one-celled living things reproduce in this way.

Kinds of reproduction. There are two main types of reproduction. One is called ***sexual reproduction*** and the other is called ***asexual reproduction.*** Sexual reproduction happens in many different ways, but it always starts with the union of two sex cells. These sex cells unite to form a single cell. This new cell is the beginning of a new individual. It can divide again and again until it forms all the cells of the new plant or animal. In sexual reproduction there are two parents. They produce the two sex cells that unite with each other. These sex cells contain genes, so that the new individual is something like both parents. Do you begin to see how heredity works? The different kinds of sexual reproduction will be described later in this unit.

Asexual reproduction is any kind of reproduction in which no union of sex cells takes place. There is only one parent. A new individual is formed by division from a cell or group of cells coming from that one parent. The offspring have the same characters as the parent.

Cell division. The simplest kind of asexual reproduction is one you already know. A single cell grows to full size. Then it divides to form two cells. There are many one-celled forms of living things that reproduce in this way. *Ameba* is a good example. First the nucleus divides by mitosis. Then the cytoplasm pinches in two, between the new nuclei (Fig. 7–1). The parent *Ameba* becomes two new *Amebas*. Each of them is only half as big as the original cell, but they take in food and grow,

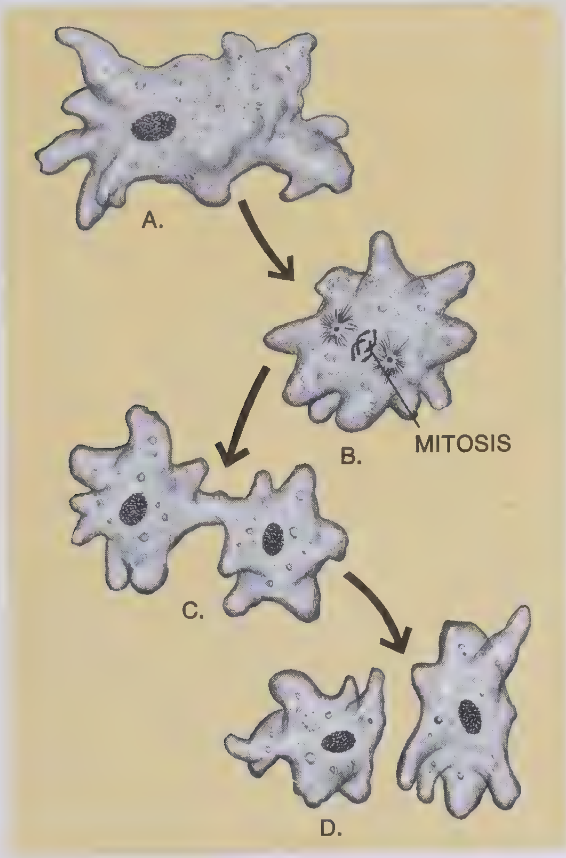


Fig. 7–1. *Ameba* dividing. In one-celled forms, cell division is a method of reproduction.

and eventually they too become large enough to divide.

Reproduction by spores. Another form of asexual reproduction is by ***spore formation.*** A spore is a single cell which is able to grow into a new plant or animal. Some spores are asexual because they are cells from a single parent. Other spores are sexual because they are formed by the union of cells from two parents.

A mushroom produces spores. If you look on the underside of a mushroom cap you will see flat layers of plant tissue which produce spores all over their surfaces (Fig. 7–2). One mushroom may form millions of spores. The tiny spore cells fall off and blow around in the wind like dust. A spore may be carried many miles before it finally

Fig 7–2. These mushrooms produce spores on their lower surfaces. The puffballs are filled with spores on their insides. (Grant Haist, Roche)

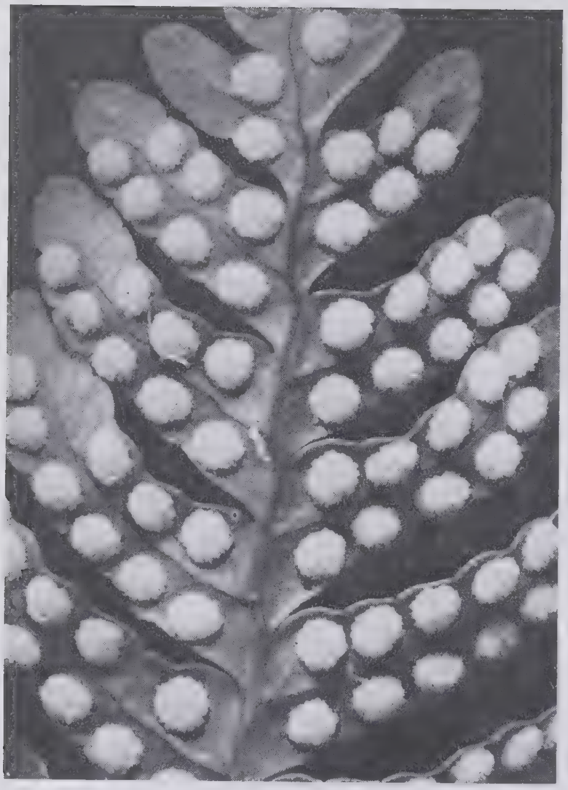


Fig. 7–3. The spots that look like clusters of fluffy cotton balls on the underside of this fern leaf are really spore cases. (Hugh Spencer)

lands. If it happens to land in a place where mushrooms can grow, it will grow into a new mushroom plant.

Molds, mushrooms, mosses, and ferns reproduce by means of spores. Perhaps you have seen small spots on the undersides of fern leaves (Fig. 7–3). These are clusters of ***spore cases.*** When they are ripe, the spore cases split open, and the spores fall out.

The big advantage in the spore method of reproduction is that millions of spores can be carried long distances by the wind. Spores spread the plants far and wide. The disadvantage of spores is that they are so tiny. They cannot carry enough stored food in their cytoplasm to give the new plant a good start. If a fern spore lands on moist soil, it may grow into a tiny fern plant. But if the surface of the soil dries out too soon, this plant will die. The underground parts will not be long enough to reach down to water. How do seed plants have an advantage in this respect?

You can see that conditions must be just about perfect if a spore is to grow. Most spores do not land where there are such perfect conditions, and they die. In order that some spores will land where they can grow, the plant must produce them by the millions. Suppose all the spores coming from one fair-sized puffball, a plant something like a mushroom, were to grow into new puffballs. These new puffballs, if put together, would make a pile bigger than the entire earth! Obviously, the spores cannot all grow. With so many spores being produced by simple living things, the air is always loaded with them and they are a part of the dust. This very minute, as you are reading this page, you are probably breathing in many different kinds of spores.

Reproduction by vegetative means. ***Vegetative reproduction*** is another form of asexual reproduction. In higher plants, the flower is the reproductive structure. It produces seeds by a sexual process. The stems, roots, and leaves are called the vegetative parts of the plant. They have to do with ordinary plant growth. If one of these parts grows into a new plant, we call it vegetative reproduction.

There are many examples of vegetative reproduction. Strawberry plants send out long, slender stems called runners, which take root and form new

Fig. 7–4. Vegetative reproduction in several types of green plants. Name the part of the plant concerned in each picture. (Bruce Trump; R. H. Noailles; Richard F. Trump; Richard F. Trump)

plants at their tips. Iris plants spread by means of thick, branching stems that grow just under the surface of the soil. New plants form at the ends of these branches. Tulips form new bulbs on the sides of the old ones. These new bulbs grow into new tulip plants. Raspberry bushes may form new plants when the tips of their stems touch the ground, take root, and grow. Potato plants store extra food in swollen underground stems. These stems are the potatoes you eat. When we wish to grow more potatoes, we do not plant seeds. Instead, we plant pieces of potato containing several buds or "eyes." These "eyes" send out sprouts which grow into new plants. Figure 7–4 shows several methods of vegetative reproduction.

It is often an advantage to man to use vegetative reproduction when starting new plants. It usually saves time. It would take two years to produce a crop of potatoes that were started from seed. By planting "pieces" of potato, a crop is produced in one season. Another advantage is that the new plant is sure to be very much like the old one. In vegetative reproduction the cells of the new plant have the same chromosomes as those in the parent plant. These chromosomes are handed on each time cells divide by mitosis.

Plants grown from seeds are more of a problem. The seeds are produced sexually. Each seed contains genes from two parents so a seed has a new gene combination. You never can be sure that it will grow into the sort of plant you want.

Now suppose you have the type of plant you require. Suppose it is a plant which you can grow by vegetative methods. You grow it this way and you know in advance exactly what will happen. Any new plant is similar to the parent plant and it contains the same genes as the parent plant.

Some of the plants raised at home can be started by vegetative means. If you want a new geranium plant you can get it by using a ***cutting***, which is also called a slip. This is what you do. Have someone allow you to cut off the end of a stem three or four inches long. Next, place the cut end of this cutting in a glass of water or wet sand. When roots begin to grow, it is time to plant the cutting in a pot of good soil. African violets can be started from leaves half buried in soil. Many plants grown in greenhouses and nurseries are multiplied by cuttings. Unfortunately, a good many plants will not grow from cuttings and must be produced from seeds.

Grafting is a very special way of using cuttings. The stem cut from one plant is made to grow on another closely related plant. Suppose a nurseryman wishes to have more Jonathan apple trees. First he plants seeds of some strong kind of crab apple. When these seeds have grown into young trees, he cuts off their tops and grafts on cuttings from a Jonathan apple tree. The Jonathan top and the crab apple base grow together. The whole top of the new tree will grow from the Jonathan cutting. The whole root system will grow from the crab apple seedling. Since the top produces fruit, this tree will yield Jonathan apples when it is big enough. Notice that ***grafting produces nothing new.*** It is simply a way to preserve and multiply a good variety of plant which we already have. When you buy fruit trees or rose

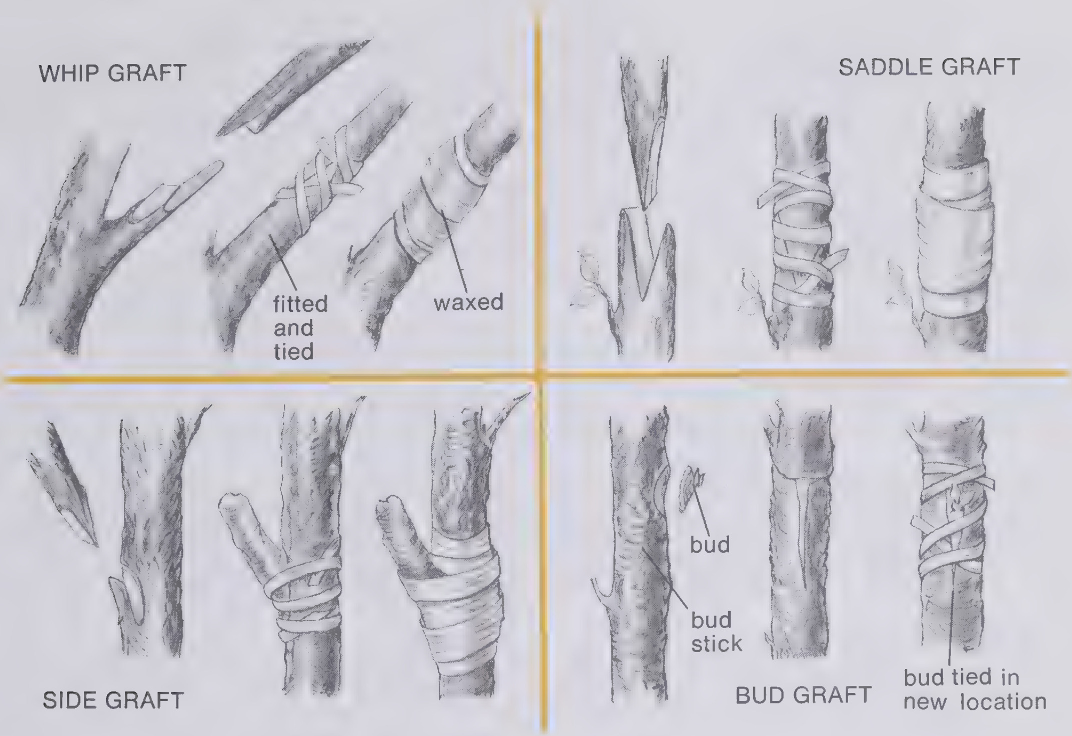


Fig. 7–5. Several forms of grafts. What parts are brought together in a graft? Why are the parts tied? Why are they coated with wax?

bushes, the nurseryman can guarantee what kind of fruit or flowers they will bear because he knows what has been grafted on these plants. You can only graft together branches of the same type of plant, or closely related plants. You cannot graft an apple branch on to a pine branch and get a pineapple!

There are several ways of making grafts, but they are all based on the same idea. In trees and shrubs there is a special layer of cells between the bark and the wood. It is called the ***cambium*** (*kam*-bee-um) ***layer***. Cells in the cambium multiply and produce new growth in the thickness of the stem. In grafting, the cambium layers of the two plants must be brought together. The two plant parts are fastened together. Then wax is smeared on the outside to prevent the living tissues from drying up. Figure 7–5 shows some of the ways grafts are made.

Reproduction in Spirogyra. You will remember that in sexual reproduction two cells unite to form one cell. A simple example of this is found in a water plant called *Spirogyra* (spy-roh-*jy*-ra). A *Spirogyra* plant is simply a long row of cells fastened end to end. Each cell has one or more spiral-shaped chloroplasts for making food, as shown in Figure 7–6. In fact, this plant lives in much the same way as *Chlorella*, except that it is made up of rows of cells instead of single cells. *Spirogyra* plants growing in the water look like a mass of green threads. These threads are merely rows of *Spirogyra* cells. The plants become longer by ordinary cell division and growth. When waves or

Fig. 7–6. The process of sexual reproduction in *Spirogyra.* Note the passageways formed between the cells. Note also how the living parts of the two cells unite to form a single, new cell. These new cells later grow into new *Spirogyra* plants.

fish break them, this results in a sort of vegetative reproduction. The cells keep on living and dividing. They may become long filaments again.

Now and again a whose mass of *Spirogyra* plants will start a simple process that is a type of sexual reproduction. First, two filaments lie side by side, as in Fig. 7–6. The cells of filament ***a*** bulge out toward the cells of filament ***b***. The cells of filament ***b*** also produce bulges. The bulges of both filaments come together and push the filaments apart so the whole structure looks like a ladder. The tips of the bulges join and thus produce a tube from each cell in filament ***a*** to each cell in filament ***b***.

While these tubes are developing, changes are taking place in the protoplasm of each cell. The protoplasm shrinks down to less than half its original size. It does this by getting rid of the water in its large vacuole. By this time the mass of protoplasm does not nearly fill the old cell wall. These shrunken cells in one *Spirogyra* filament move across, through the

tubes, to join the cells in the other filament. Each of these pairs of cells flows together, forming a single cell. Now one filament has lost all of its living material. But each cell in the other filament contains material from two cells (see Fig. 7–6).

Each of these new cells can grow into a new *Spirogyra* plant, but they do not do it right away. They form heavy cell walls around themselves and become what are called *resting spores*. A resting spore can go without water for a long time, so here is a way that the plants are preserved when the pond they live in dries up. When fresh, cool water floods the pond again, the walls of the resting spores split open. The cell of the spore grows and divides over and over again. A new *Spirogyra* plant is formed.

Reproduction by sperms and eggs. The *Spirogyra* method is the simplest kind of sexual reproduction because the ordinary body cells of the plant act as sex cells. Most other plants and animals produce special cells for this purpose. Usually there are two kinds of cells. One type is tiny and has a hairlike tail with which it can swim. The other type is larger and has no power of movement. This larger kind of sex cell is called an ***egg cell***. The small, swimming one is called a ***sperm***. A sperm can swim to an egg cell and unite with it. Their nuclei join and form a single nucleus. This process is called ***fertilization***.

A simple example of reproduction by sperms and egg cells is found in *Hydra*. *Hydra* is a little water animal about an eighth of an inch long. It has a tubelike body with a mouth at the top. Around the mouth is a ring of armlike structures called *tentacles*. You will learn a number of things about the *Hydra* in Chapter 27, but right now we are only interested in its method of reproduction. Most of the time *Hydra* reproduces asexually by a process called ***budding***. Budding in *Hydra* is really no different from vegetative reproduction in plants. A bulge forms in the body wall. This is called a bud. Its outer end develops tentacles and a mouth. When it is full grown the bud breaks loose and becomes a new *Hydra*.

When *Hydras* reproduce sexually two other kinds of bulges appear on the sides of their bodies. In one kind of bulge, a single large cell develops. This is an egg cell. In other bulges, large numbers of sperms are produced. When these sperms break out into the water, they swim about until they reach the egg cells. A single sperm unites with each egg cell. This fertilized egg cell can then begin to divide. It divides many times to form the cells of a new *Hydra*.

All but the very simplest living things reproduce by means of sperms and egg cells. A sperm is a male cell. An egg cell is a female cell. This is the difference between males and females. A male produces sperms. A female produces egg cells. In some animals such as *Hydra* the sexes may be separate or one animal may produce both sperms and egg cells.

You might think that, because the egg cell is bigger, it would have more influence on heredity than the sperm. This is not true. Remember, the nucleus controls heredity. The nucleus of the sperm contains just as many chromosomes as the nucleus of the egg cell does. Both cells have equal effect on the heredity of the new *Hydra* they

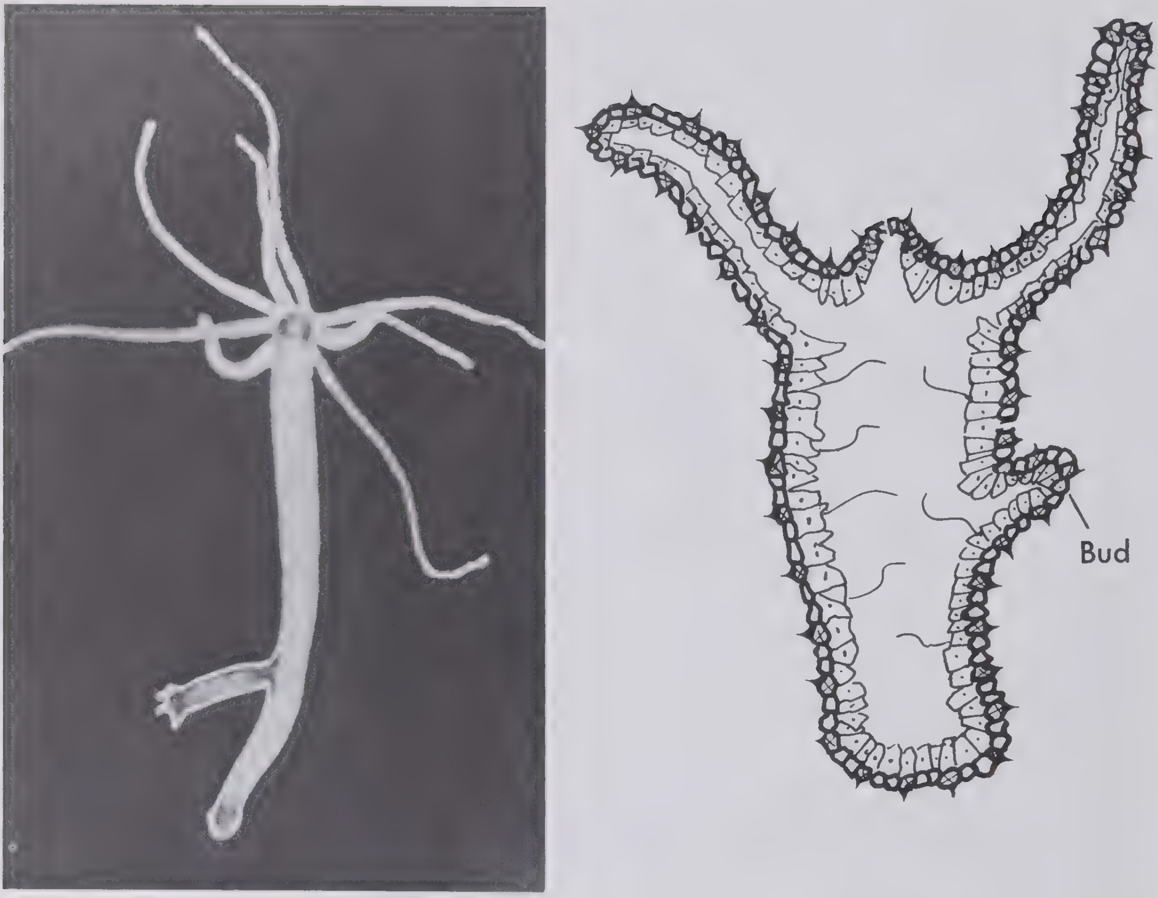


Fig. 7–7. Left: a photograph of a *Hydra* that has a bud growing out from the body wall. Right: a diagram showing how the bud of a *Hydra* forms on the body wall. (Hugh Spencer from the National Audubon Society)

produce. The large cytoplasm of the egg cell often contains a great deal of stored food. This gives the new animal a strong start in life.

Advantages of sexual reproduction. You may wonder why sexual reproduction is important. After all, it is not as sure as the asexual method. The sperm may fail to find the egg cell. But suppose there was no sexual reproduction. Suppose, also, that some members of the species had one very good trait and were more successful because of this trait. Suppose other individuals had different good traits. Would it be possible for one individual to inherit all of them? Obviously not by asexual reproduction. Asexual reproduction can only hand on what is present in a single parent. In sexual reproduction, however, an egg cell may carry the gene for one good trait. The sperm may carry the gene for another. The new individual may then inherit both good traits. It will have a better chance of surviving. It may live to reproduce more often than other

individuals, so that the combination of good traits will become more and more common in that kind of plant or animal.

At the same time, some individuals may be unlucky enough to inherit several genes for traits which handicap them. They will probably have few offspring and die young. Their genes die with them. This is how, in nature, genes for undesirable traits are "lost," and those for good traits become "standard equipment."

ACTIVITY

Observing spores and sex cells. Obtain a culture of the simple water mold, *Allomyces arbusculus* from a biological supply company. Place bits of this mold in small containers of water (Petri dishes will do) along with a few boiled radish seeds. Crack the seeds open before putting them in the water. In about a week you will see that your seeds are covered with a fuzzy white growth of *Allomyces* plants. Pull some loose with tweezers and make temporary mounts of them on microscope slides. You will see that the mold plants consist of simple branching threads filled with protoplasm. Along these threads are rounded globe-shaped structures which produce either spores or sex cells. You may see spores break out of their spore cases and swim away through the water. Each spore is a cell with a long hairlike tail. It swims through the water with this tail. The sex cells look just like the spores except that some of them are only half as big. You may be lucky enough to see a large and small sex cell meet in the water. See how they flow together to form a single cell. This cell can grow into a new plant. So can the spores.

ACTIVITY

Look for *Spirogyra* growing in ponds, streams or ditches. You can tell it from similar plants because it feels very slippery when held between the fingers. Place some in jars of water and bring it to school. Put the jars near a window. Observe a little of this *Spirogyra* material under the microscope and see the long spiral chloroplasts. Keep observing the *Spirogyra* from day to day. Being brought into a warm classroom often causes *Spirogyra* to start sexual reproduction. You may be able to see the tubes forming between cells. You should also be able to find some filaments with empty cell walls and some containing the resting spores.

CHECK YOUR FACTS

1. **What is the difference between sexual and asexual reproduction?**
2. **When does cell division result in growth, and when does it result in reproduction?**

3. What is a spore? What plants reproduce by means of spores?
4. What are the advantages and disadvantages to the plant in reproducing by means of spores?
5. What is vegetative reproduction? Give some examples.
6. Why are fruit trees produced by grafting?
7. How is grafting done?
8. In *Spirogyra,* how do cells unite in sexual reproduction?
9. What becomes of the cell that is formed by two *Spirogyra* cells?
10. What is the difference between sperm cells and egg cells?
11. How does the sperm cell of a *Hydra* reach the egg cell?
12. What do we call the union of a sperm with an egg cell?
13. What happens to an egg cell after it has been fertilized?
14. What advantage does asexual reproduction have over sexual reproduction?
15. What advantage does sexual reproduction have over asexual reproduction?

CHAPTER 8

Reproduction in Flowering Plants

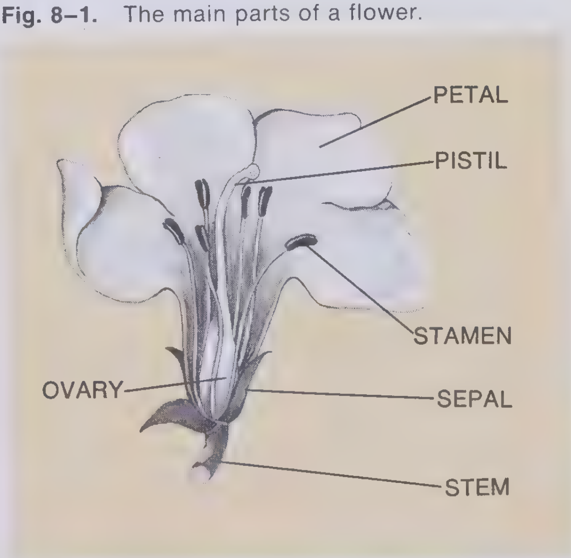
Flowers are the reproductive structures of the higher seed plants. Most of these plants grow on the land. But you have seen some of them, such as pond lilies, growing in the water. Sex cells are developed by flowers. Some flowers form only egg cells and others form only the sperms. Still other kinds produce both egg cells and sperms.

Parts of a flower. Figure 8–1 shows the main parts of a flower. In the center is the ***pistil.*** The lower part of the pistil is thicker than the upper part. This lower part contains the ***ovary*** (*oh*-va-ree). The ovary is the part of the pistil in which the egg cells are formed. The egg-producing organs of animals are also called ovaries.

Around the ovary are a number of long, slender stalks with thicker structures at their upper ends. These are the ***stamens*** (*stay*-mens). When the end part of the stamen is ripe, it splits open. A large number of tiny particles come out through the openings. These are called ***pollen grains.*** If you rub your finger over the stamens of a flower you will see some yellow dust on your skin. This is pollen. Each pollen grain is built like a cell. It has a cell wall, membrane, and cytoplasm. However, it has first two and later three nuclei. It is really a three-celled structure even though there are no separate walls and membranes between the three nuclei. The walls of pollen grains are often covered with grooves, ridges, spines, or bumps. An expert can look at pollen grains under the microscope and tell what kind of plant they came from.

Around the stamens is a circle of ***petals.*** These are the bright, showy parts that make flowers attractive to look at. Around the petals are the ***sepals*** (*see*-puls). In most flowers the sepals are green and leaflike. They cover the flower bud before it opens.

Fig. 8–1. The main parts of a flower.

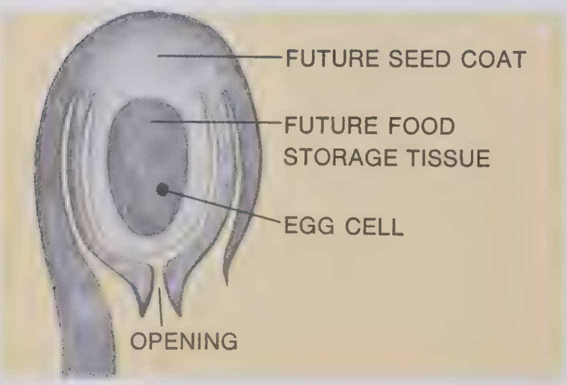


Remember that flowers are not all alike. Some types have more than one pistil. Some have a pistil, but no stamens. Some have no sepals or no petals. Some plants have many tiny flowers grouped together so that they look like a single large flower. You have seen the blooms of dandelions, chrysanthemums, asters, and daisies. Look at one of them closely, and you will see that they are made up of many tiny flowers. So is the blossom of a clover plant.

Fertilization in flowers. There are hollow spaces inside the ovary which contain small round objects on short stalks. These round structures are future seeds. Each of these future seeds is made of more than one cell, but one particular cell on the inside is the egg cell (Fig. 8–2).

Before fertilization can take place, a pollen grain must land on the upper end of a pistil. Of course it must be a pistil of the same kind of flower as the one from which the pollen grain came. The arrival of the pollen on the pistil is called ***pollination.*** The end of the pistil is covered with a sticky juice that holds the pollen grain in place.

Fig. 8–2. A future seed from the ovary of a flower. Remember that this is only a diagram which shows just the most important parts. Actually, there are many cells present besides the egg cell.



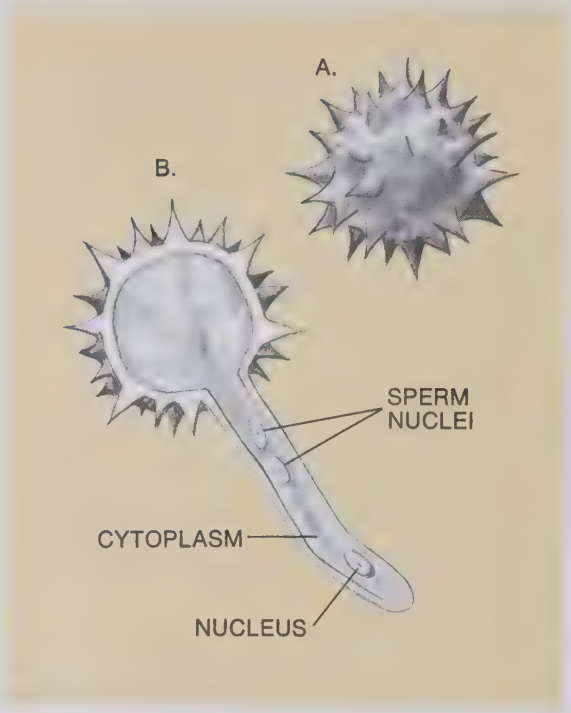


Fig. 8–3. A pollen grain before and after it has formed a pollen tube.

What happens when a pollen grain gets on the upper end of a pistil? First, the pollen grain begins to grow. As it absorbs water and food from the pistil, the pollen grain swells enough to crack its wall open. Then it grows downward in the form of a long slender tube, called the ***pollen tube.*** This is shown in Figure 8–3B. The tube grows down through the pistil. It makes its way by digesting the tissues of the pistil. Notice in Figure 8–3B that there are now two sperm nuclei in the pollen tube. Either one of these nuclei can act as a sperm and fertilize an egg cell. When the end of the pollen tube reaches the hollow part of the ovary, it grows in through a tiny hole in the end of the future seed. Then the end of the tube

bursts open. The sperm nuclei escape from the tube and one of them unites with the egg cell. This is the act of fertilization.

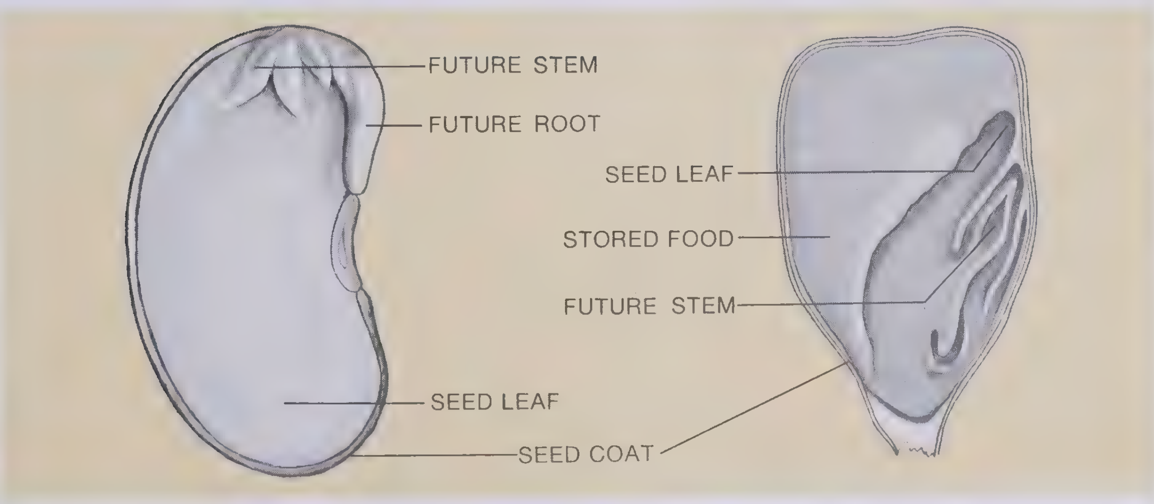
Development of the seed. As soon as the egg cell and sperm nucleus have united, the fertilized egg begins to divide, grow, and divide again, many times. A very small plant is formed in this way. It is called the ***embryo*** (*em*-bree-oh). It has one or two seed leaves and parts that will become a root, a stem, and a stem tip. When it has formed all of these parts, the little plant stops growing. Meanwhile, the tissues around the embryo are growing to form the rest of the seed. Not all seeds are alike, but they always have an embryo, an outside seed coat, and a stored food supply. The stored food may be in cells between the embryo and the seed coat, as shown in the corn seed. (Fig. 8–4) But in some plants the food is stored in the seed leaves, as shown in the bean seed (Fig. 8–4).

A seed will generally grow when it has moisture and the proper temperature. Water soaks through the seed coat, and the embryo begins to develop. Its root grows down into the soil, and its stem grows up into the air. Leaves spread out in the light. The stored food in the seed is used during this early growth process.

A seed may live for a long time before it begins to grow. Wheat or corn seeds may still be able to grow after six or seven years. Seeds of the common pigweed can still grow after 40 or even 60 years. Lotus is a kind of big water lily. Its seeds may grow after as much as 100 years.

As you can see, growth from a seed has several advantages. In the first place, the seed contains a many-celled plant, the embryo, which is ready to grow. In the second place, the seed's

Fig. 8–4. This is a cutaway view of a bean seed and a corn seed. Note that the corn has special tissue for food storage. In the bean the embryo fills the entire space inside the seed coat. The bean stores food in its enlarged seed leaves. Which parts of these seeds are also parts of the embryo? Would all cells in the seeds have the same kinds of genes?



supply of stored food gives the young plant a good start. By the time this food is used up, the plant has roots in the ground to obtain water and leaves in the light to make more food.

Methods of pollination. You may have wondered how the pollen arrives on the end of the right kind of pistil at just the right time. There are two main ways in which this happens. The pollen grains are usually carried either by wind or by insects.

Bees are insects that often carry pollen. Other insects such as wasps, moths, and butterflies sometimes carry pollen, too. When a bee crawls into a flower, its hairy surface becomes covered with pollen. When the bee visits another flower, some of this pollen rubs off. Pollen thus gets on to the pistil of the flower. This is an accident so far as the bee is concerned.

If you want someone to work for you, you usually have to pay him. Do you know how the flower "pays" the bee? Bees obtain all of their food from flowers, and in turn the flowers are pollinated by bees. Bees obtain two kinds of food from flowers. One is pollen. The flower produces enough pollen both for bee food and for pollination. The other food is nectar. This is a sweet juice which is produced by cells near the base of the petals. Bees crawl into the flower to drink this nectar. It is carried back to the hive in a special part of the bee's stomach. Pollen is carried packed on the bees' hind legs. In the hive the pollen is stored. The nectar is made into honey.

Bees usually visit only one kind of flower on a single collecting trip. This means that the right kind of pollen is almost sure to land on each pistil. Flowers are often shaped in some spe-

Fig. 8–5. A bee pollinating a flower. Why does the bee do this work? (Stephen Dalton from L. Hugh Newman's Natural History Photographic Agency)

Fig. 8–6. Photographs of several different seeds and fruits. How is each of these scattered? Top left: flowering dogwood (Jack Dermid); top right: columbine (Paul Villiard); center left: beggar tick (R. H. Noailles); center right: acorn (R. H. Noailles); bottom left: milkweed (Roche); bottom right: maple (Grant Heilman)

cial way which makes the bees' work easier. Certain petals are large and form "landing fields." The pistil may grow down over this landing area. Then the bees' backs rub against it when they crawl in to get the nectar.

Perfume and showy petals may help bees to find the flowers. Wind-pollinated flowers do not need any such display. They have no perfume, and their petals are either very small or missing entirely. You may never have noticed wind-pollinated flowers, yet they are very common. All of our grasses and most of our shade trees are pollinated by wind. Their flowers are very small and generally have just a pistil and stamens. The stamens produce large numbers of very small pollen grains. These are carried by the wind like spores. Some of them are almost sure to land on the right kind of pistils. Of course, most of them are just wasted landing in all sorts of other places. In some plants, pollen falls from the stamens to pistils on the same plant. In this case, the plants pollinate themselves.

The function of fruits. A fruit is the ripened ovary of a flower. Fruit development starts as soon as pollination takes place. Some fruits are ***fleshy fruits***, such as a peach or a berry. Others are ***dry fruits***, such as a burr or a pea pod. You usually think a fruit is something like an apple or an orange that you can eat. You think it is the sort of thing one can buy in markets. But to a biologist, a cockleburr is also a fruit. So are a lot of other dry structures that develop around seeds. A fruit may simply protect the seed during its development. But it also may serve to scatter seeds. Suppose you walk past a tree covered with peaches. You pick some, and, as you walk along, you eat the fruit and throw away the seeds. In the same way, wild animals scatter the seeds of many fruits.

Some dry fruits are also carried about by animals. Have you ever discovered burrs sticking to your clothing? When you pull the burrs off they may land in new places where their seeds can grow. The hooked spines on the burr also stick to the fur of animals that brush past them. You may have seen dogs scratching burrs out of their fur.

When a pea pod is dry enough, it suddenly splits open, throwing the seeds out in all directions. The acorn shown in Figure 8–6 may be carried off by a squirrel and buried in the ground where it may sprout later on. Many seeds are distributed by the wind. Either the seed or the fruit has some sort of wings or fuzz which catch in the wind to carry the seed long distances (Fig. 8–6). The seeds of dandelions, maples, milkweeds, and cottonwoods are all scattered in this way.

The plant life cycle. Some seed plants complete their whole life cycle in a single growing season. The seed sprouts in the spring. By autumn the plant produces seeds of its own. The old plant dies, and only the seeds remain. Zinnias, marigolds, corn, wheat, beans, and peas are examples of this.

Other seed plants take two growing seasons to complete their life cycles. In the first season they develop stems, roots, and leaves, but do not bear flowers. During this first year they store food. Often the parts above ground die during the next winter. But the plants grow up again from their un-

derground parts during the second season and this time they produce flowers and seeds. Then they die. Beets, carrots, foxglove, and Canterbury bells are such plants.

Finally, there are plants which live through several growing seasons producing seeds each year. Lilies, columbines, and daisies do this. So do trees, shrubs, and many of the vines and grasses. In fact some plants live for hundreds of years.

ACTIVITY

A study of flowers. Bring in as many kinds of flowers as you can. By trading flowers each of you can see many kinds. If it is winter you may be able to obtain leftover flowers from a florist or a funeral director. Or you can cut branches from fruit trees or flowering shrubs and put them in a vase of water in the warm room. Soon their flower buds will open up.

Examine each flower carefully. Find the sepals, petals, stamens, and pistil. Are these parts the same in every flower? Does each kind of flower have the same number of flower parts? Try to picture where a bee would land and what flower parts it would touch. Make temporary mounts of pollen from different flowers. Do the pollen grains look the same under the microscope? Use a needle to split open the ovaries of different flowers. Do they have the same number of future seeds inside?

CHECK YOUR FACTS

1. **What is the function of the flower?**
2. **Draw a picture of a flower and label all of the important parts.**
3. **Where are the sperm cells developed in a flower?**
4. **Where are the egg cells of a flower located?**
5. **How does the sperm cell of a flower reach the egg cell?**
6. **What is pollination? How is it different from fertilization?**
7. **What are the important parts of a seed?**
8. **What part of the flower becomes a fruit?**
9. **What are the two main ways in which pollination takes place?**

CHAPTER 9

Reproduction in Higher Animals

In Chapter 7 you learned how *Hydra*, a simple animal, reproduces. The sperm swims through the water to the egg. The fertilized egg grows into an adult *Hydra*. You are now about to study reproduction in higher, more complex animals. You will find that reproduction in these animals is not so very different from reproduction in *Hydra*. Eggs and sperms are produced, and the fertilized egg develops into a new animal.

Reproduction in fishes. Female fish have ovaries which produce eggs. The eggs pass through tubes called ***oviducts*** (*oh*-vi-dukts) which lead from the ovaries to the outside. Male fish have ***testes*** (*tes*-teez) which produce sperm cells. Sperm ducts lead from the testes to the outside. When sperms are ready to leave the male they are contained in a liquid called ***semen*** (*see*-men).

Breeding habits differ, but most fish lay and fertilize their eggs in the water. In the mating season males and females are attracted to each other. As the female lays her eggs, the male fish swims close behind or beside her. The male sends out semen through his sperm ducts. Sperms from the semen swim through the water and fertilize the eggs.

Different kinds of fish lay their eggs in different places. Some fish lay their eggs on rocky reefs, some on gravel bottoms, and some scatter them among water plants, or just out in the open water. Usually the parents leave as soon as the eggs are laid and fertilized. Most fish give no care to their young. But in some kinds of fish the male stays near the "nest" and protects the eggs until they hatch. Fish of the bass family are one of the types that do this. One kind of male catfish carries the fertilized eggs in his mouth until they hatch!

Since most fish eggs are unprotected,

Fig. 9–1. A male stickleback guarding his nest. (Douglas English/Annan Photo Features)

many of them are lost. They are eaten by fish and other water animals. Fish species might be wiped out by these losses if it were not for the large numbers of eggs laid. A single female fish may lay thousands or even millions of eggs each year. If only one in a thousand lives, a good many new fish are produced.

Reproduction in frogs. Adult frogs and toads are air-breathing animals but they return to the water to lay their eggs. On evenings in the spring many kinds of male frogs gather in the ponds and sing. We are not sure that they sing to attract female frogs. They may also sing to warn off other males. The males and females, however, are attracted to each other and they pair off.

A female frog often is so full of eggs that she cannot lay them by herself. The male helps by squeezing the sides of her body with his front feet. Together they force out some of the eggs. This process is repeated many times and may take a whole day. Each time a batch of eggs is laid, the male sends out a cloud of sperms over them. The sperms swim to the eggs and fertilize them.

You may find a mass of frog eggs in the water and wonder how they could all have come out of one small frog. The outside layer of clear jelly which surrounds each egg does not swell up until after it is in the water. This makes the whole egg mass bigger than the frog it came from. Like most fish, frogs leave their eggs, giving them no protection. The young tadpoles which hatch from the eggs are like fish in most ways. They swim with their tails and get oxygen through their gills. Only after a period of growth do they develop legs and lungs and other organs. Finally, the tail is absorbed, and the tadpole becomes a frog. Figure 9–3 shows stages in the development of a frog.

Fig. 9–2. Frog eggs. Note the clear jelly which surrounds each egg. (Lynwood M. Chace)

Inside fertilization. Even though a frog is a land animal, it must return to the water to produce its young. The higher land animals include ***reptiles***, such as snakes, turtles, and lizards. They also include the ***birds*** and the ***mammals***. Mammals are warm-blodded, hairy animals, such as dogs, horses, rats, giraffes, and man. Each group has its own special way of reproducing.

In all three groups, the egg cells are fertilized within the body of the female. First, a male and a female come together and mate. In this mating process, the male puts semen into the oviduct of the female. The sperms swim upward in the film of moisture that clings to the linings of the oviducts. Hundreds of millions of sperm cells are released at a single mating. One of these may unite with one egg cell and fertilize it. This method of inside fertilization makes sexual reproduction possible on land. Actually,

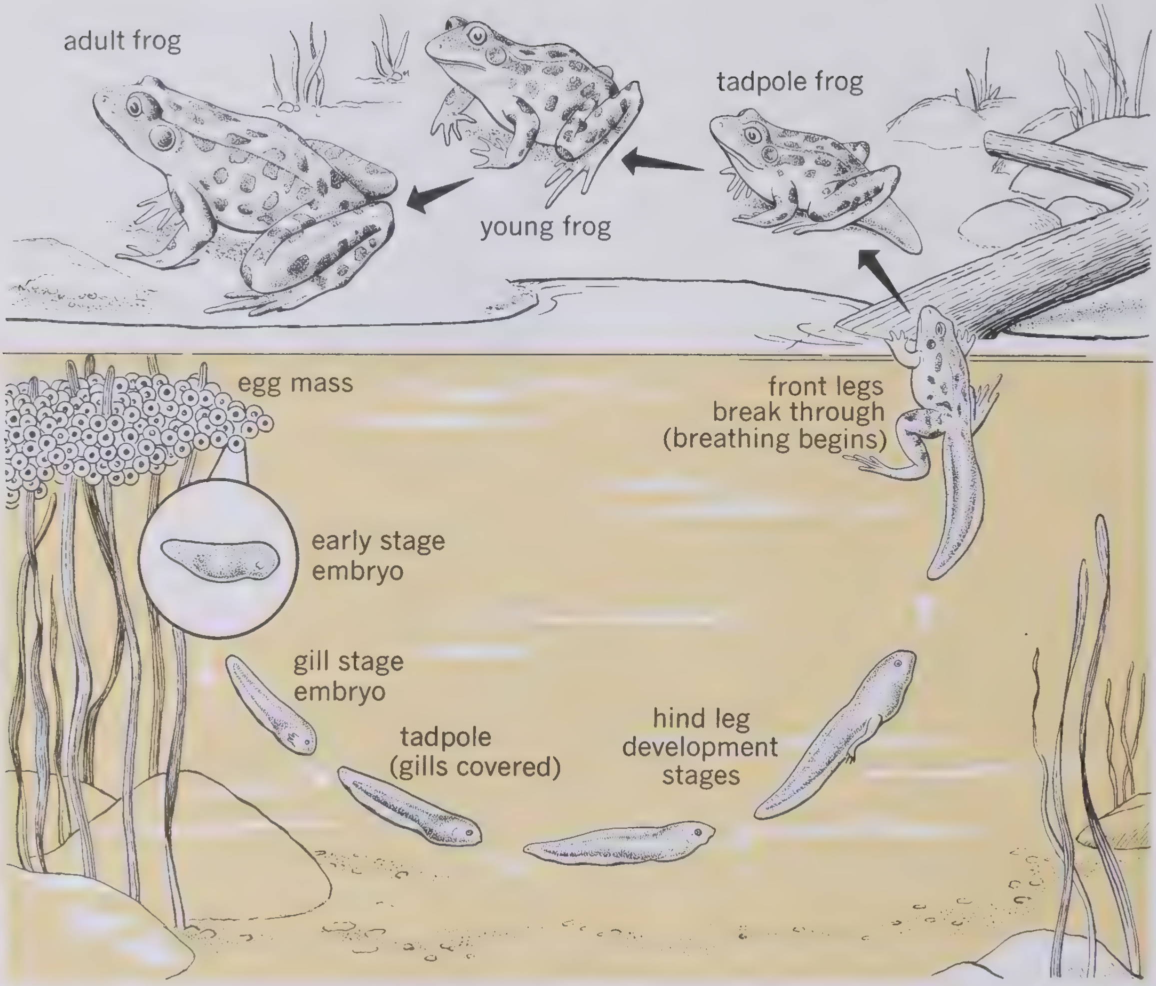


Fig. 9–3. Stages in the life cycle of a frog.

some kinds of fish also use inside fertilization. The fertilized eggs may stay in the oviducts of the fish and hatch there, in which case these fish produce living young. Guppies are a good example.

Reproduction in reptiles and birds. The eggs of fish and frogs are small and delicate, like little balls of jelly. They would soon dry up and die if they were left out in the air. Reptiles and birds have a type of egg that can be laid on land. You have seen birds' eggs. Reptile eggs are about the same. Some turtle eggs have a tough leathery covering but others have a hard shell. The only living part is the small white spot on the egg yolk that always floats upward when you break an egg into a dish. The yellow yolk material is a supply of stored food. This food from the yolk is used by the young bird or reptile during its development in the egg.

A hen's egg is fertilized when it first enters the oviduct. As the fertilized egg passes along, cells of the oviduct add the egg white. Then three thin

Fig. 9–4. An early stage in the growth of a chicken embryo. How is the young bird getting its food?

membranes are added around the egg white, and the egg gets its shell. Finally the egg is laid.

Once the eggs are laid, the story for the reptiles is different from that of the birds. Most reptiles lay their eggs and leave them. Turtles, for instance, bury their eggs in the sand and walk away. When the little turtles hatch, they must dig their way out and must care for themselves. The parents take no interest in them. Birds, as you know, usually protect their eggs and feed the young. This means that each young bird has a much greater chance of living. Not so many eggs need to be laid to keep the number of birds about the same.

Birds' eggs do not start to develop unless they are kept warm or *incubated.* The heat they need is supplied by the bodies of the adult birds when they sit on the eggs. They must continue to sit on them day and night until the eggs hatch. Then the young birds are fed and protected until they are grown. Some birds hatch quickly but are very helpless at first. Robins, for instance, hatch in just 14 days, but they are blind, naked little things. About all they are able to do is open their mouths. The parents work hard, gathering food and stuffing it into these open mouths. Other birds take longer to grow in the egg and are more fully developed when they hatch. Chickens take 21 days to hatch, and ducks take 28. But chicks and ducklings are able to follow their mothers and pick up their own food right away.

Mammal reproduction. Most mammals, as you know, bear living young. They are not the only animals that do this. Some female fish, like the guppies, and some female snakes, like garter snakes and rattlesnakes, never lay their eggs.

Fig. 9–5. Snake eggs hatching. Will the mother ever take care of these young snakes? (Lynwood Chace)

Fig. 9–6. Are any differences in the reproduction of birds and reptiles shown in this photograph? (Bureau of Sport Fisheries and Wildlife)

Fig. 9–7. The duckbill. This primative mammal, which is a native of Australia, is a type which lays eggs. (Australian News and Information Bureau)

They keep the eggs in their bodies until development has taken place. These young fish and snakes receive food to grow from the supply stored in the eggs. When the young are fully developed, they are born. This is not much different from the egg developing after it has been laid, but it means that the egg is protected in the body of the parent while development goes on. A young animal developing in an egg or in the oviduct of the mother is called an *embyro*.

In mammals there are really three types of reproduction. Though most mammals give birth to young, the duckbill (Fig. 9–7) and the spiny anteater lay eggs, just like most reptiles. But once the eggs are laid, the mother protects them. When they hatch, she feeds the young animals on her milk. Mammals are the only animals that produce milk to feed their young.

The second type of mammal reproduction is found in kangaroos, opossums, and other pouched mammals. These animals produce very small eggs which develop right in the oviduct. There is not much yolk material, so the embryo must absorb what food it can from the mother through the lining of the oviduct. The young are born when they are very small and only partly developed. A newborn opossum is smaller than a honeybee. A 400-pound kangaroo gives birth to young about the size of peanuts. The only well-developed parts of these young animals are their front legs. They use them to climb into the mother's pouch. This pouch is a warm, furlined pocket on the underside of the body. The nipples to the milk glands are located in the pouch. The young animal attaches its mouth to the nipple and does not let go until it is much older and more mature. So the young kangaroos live in the pouch where they are protected, warm, and well fed. They leave the pouch when they are big enough to walk about on the ground. Then they grow slowly to adult size.

Fig. 9–8. A kangaroo with its young which is about nine months old and is almost ready to leave its mother's pouch. (Australian News and Information Bureau)

In North America there are no egg-laying mammals and only one type of pouched mammal, the opossum. All of our other mammals are the type called ***placental*** (pla-*sen*-tul) ***mammals*** because their unborn young are nourished by a special structure called the ***placenta***. This is the third type of reproduction found in mammals. Figure 9–9 shows the female reproductive organs in an animal which has

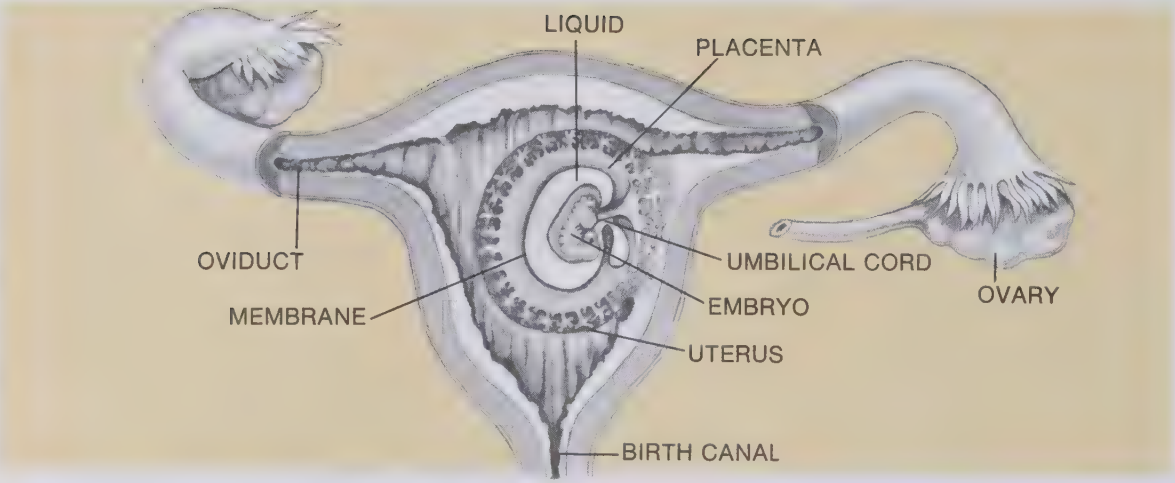


Fig. 9–9. The developing embryo in a mammal which produces one young at a time.

one young at a time. Many mammals produce several young at a time as shown in Figure 9–10. There are two ovaries in mammals, which produce tiny egg cells. These egg cells are smaller than the period at the end of this sentence. An oviduct leads away from each ovary. The two oviducts join to form a "Y." The lower end of the Y is the birth canal leading to the outside. The region where the three parts of the Y come together is called the ***uterus*** (*yoo*-ter-us). The uterus has thick, muscular walls and a rich blood supply. It holds the embryo during its development, which may take a fairly long time.

An egg cell leaves the ovary and enters the upper end of an oviduct. If mating takes place at this time, the sperms placed in the birth canal by the male will swim up through the uterus into the upper part of an oviduct. Here one of the sperms will fertilize the egg cell. Now the fertilized egg cell begins to divide. It moves down into the uterus and by this time it is already a many-celled structure. It is, in fact, an *embryo*. It will grow and develop.

The little embryo becomes attached to the lining of the uterus. It absorbs nourishment from the blood vessels in the uterus. At first, the embryo is a ball of cells that are all alike. This ball has a layer of cells on the outside and another on the inside. Then a middle layer of cells forms between the first two. Now the embryo has three cell layers. All of the body parts develop from these three cell layers. Your outer skin and your nervous system developed from the outer layer of cells. Your stomach and intestinal linings came from the inner layer. The middle layer produced your muscles, bones, and blood vessels. Biologists have always marveled at how a fertilized egg cell can give rise to trillions of cells of many types, all perfectly arranged to form the adult body.

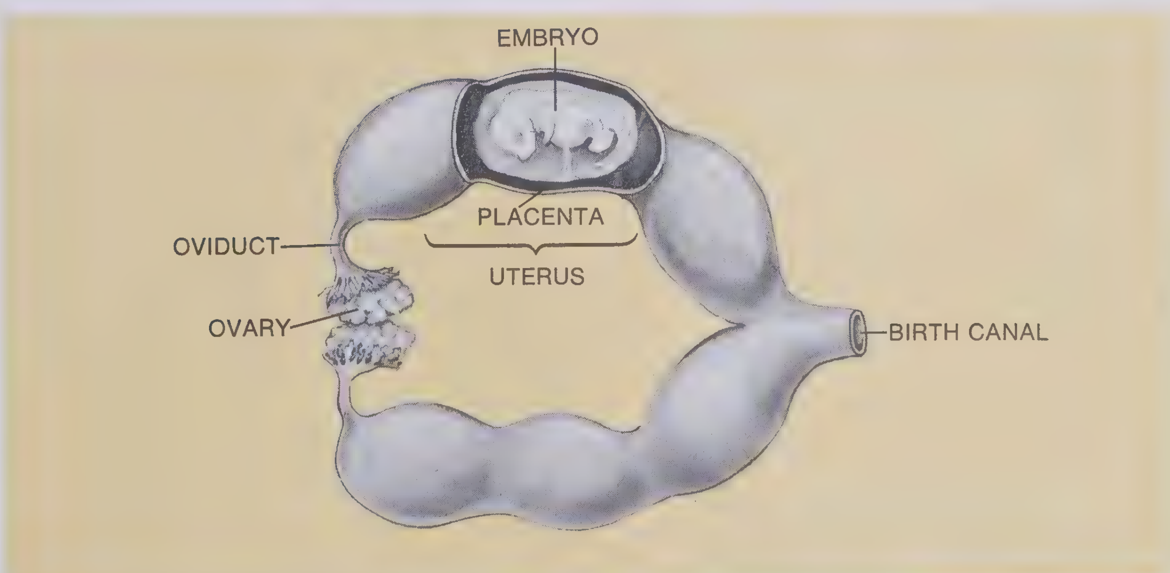
Development and birth. In placental mammals the special organ called the placenta grows tightly against the wall of the uterus. The placenta is con-

nected with the embryo by a tube called the ***umbilical*** (um-*bil*-i-kul) ***cord*** (Fig. 9–9). This cord contains three blood vessels. Two of them carry blood from the embryo to the placenta. One brings blood to the embryo. Within the placenta, only thin membranes separate the blood of the mother from the blood of the embryo. Dissolved substances pass through these membranes. Food and oxygen pass from the mother's blood to the embryo's blood. Carbon dioxide and other wastes pass from the embryo's blood to the mother's blood. The mother's excretory system gets rid of these wastes. The embryo has special membranes surrounding its body. These membranes contain a liquid so that the young mammal develops in water, just as a fish does. Bird embryos also have liquid-filled sacs around them as they develop inside the eggshell. A stalk connects the bird embryo with its food supply in the egg yolk in much the same way that the umbilical cord connects the mammal embryo with the placenta. The stalk is the lifeline between the embryo and the placenta.

Thus the young mammal is nourished and grows. Tissues, organs, and systems are formed in its developing body. Finally, the time for birth arrives. The walls of the uterus begin to contract. The young animal is forced out through the birth canal. When this happens the umbilical cord is broken. Now the new-born animal must do a very important thing—it must begin to breathe. Most female mammals lick their newborn young all over, starting with the nose. This clears the nostrils and helps the young animal to start breathing. Human babies often have their bottoms slapped to shock them into breathing.

When the young mammal has been born there is no further use for the placenta. It passes out of the mother's body and is commonly called the after-

Fig. 9–10. The type of mammal uterus which produces several young at one time. How many are growing in this one?



birth. A scar is left on the abdomen of each mammal where the umbilical cord was attached before birth. This is the navel.

Care of the young. Like birds, some mammals develop more fully before birth than others do. Newborn puppies and kittens are blind and helpless. They must be kept in a protected place and fed on milk for quite a while before they can come out and follow their mother around. But a young calf gets up on its feet and follows its mother in about half an hour after it is born. Wild, grass-eating animals are always on the move. If their newborn young could not keep up with the herd, they would be killed by their natural enemies, which are always on the lookout for stragglers.

Since both the birds and the mammals care for their young, we find similar kinds of family organizations in the two groups. There are some, for instance, in which the female alone does all the work of raising the young. Hummingbirds are an example of this. The male deserts the female soon after mating. Black bears are an example of a mammal in which only the mother cares for her cubs.

Another arrangement is found among birds such as chickens and pheasants, and among mammals such as sheep and deer. In these groups one male mates with several females. In some cases he may stay with this group of females and protect them while they care for their growing young.

Still other birds and mammals mate two by two, and both parents help raise the young. Most of our common song birds are of this type. Male and female share the work of building the nest, sitting on the eggs, and feeding the young. Wolves and foxes are mammals which form this sort of family group. Both parents prepare the den. Both protect and feed the young. Other wolves in the pack may also help.

ACTIVITY

Animal development. Find some frog eggs and place them in an aquarium. In the spring they may be found in almost any pond where frogs are singing. At other times of year they may be bought from biological supply companies. Use plenty of water. If frog eggs are crowded they will die. Watch the changes that take place in the eggs as they develop. One or two at a time can be taken out and observed under a lens. Make a drawing of the embryo at each stage of its development. When can you first see eyes? When does movement begin? How well can the tadpoles swim when they hatch?

Remove the clear jelly cases from the water as soon as the eggs have hatched. The tadpoles can be fed bits of canned spinach and boiled egg white. Keep track of their development. When do the outside gills disappear? When do hind legs appear? Front legs? Does the tail drop off? What change takes place in the mouth?

CHECK YOUR FACTS

1. Describe how the eggs are laid and fertilized by fish and by frogs.
2. How does fertilization take place in the reptiles, the birds, and the mammals?
3. How are reptile and bird eggs better adapted to land conditions than the eggs of fish and frogs?
4. How does the reproduction of birds differ from the reproduction of reptiles?
5. What are the three types of reproduction in mammals?
6. How does care of the young by parents help birds and mammals to survive?

CHAPTER 10

Heredity

People have always wondered how living things inherit their structures. Early studies of this problem did not get very far because scientists did not use controlled experiments. However, about 100 years ago a man named Gregor Mendel made real progress.

Mendel was an Austrian monk. He lived in a monastery that had a large garden. He was interested in growing plants and in their heredity. So he began to test the heredity of common garden peas. You can repeat his experiments today in a backyard garden, if you have one.

Mendel's experiments. In one of Mendel's experiments, he took pollen from tall pea plants and dusted it on the pistils of short pea plants. He saved the seeds that were produced by this cross and planted them the next year. The embryos in each of these seeds had one parent that was tall and one that was short. When individuals have mixed ancestry like this we call them ***hybrids.*** What kind of plants would these hybrids grow into? You might expect them to be an in-between size, but this is not what happened. Every one of these hybrid peas grew into a tall plant. There were no short ones or in-between ones. (Fig. 10-2B).

Mendel wondered if the trait for shortness had been lost. To find out, he pollinated the pistils of some of these hybrid peas with pollen from hybrid peas. When he planted the seeds produced by this cross, the results were different from those of the first experiment. Out of hundreds of such seeds that were planted, about

Fig. 10–1. Mendel in his garden. His experiments led to the first scientific information about heredity. (The Bettman Archive)

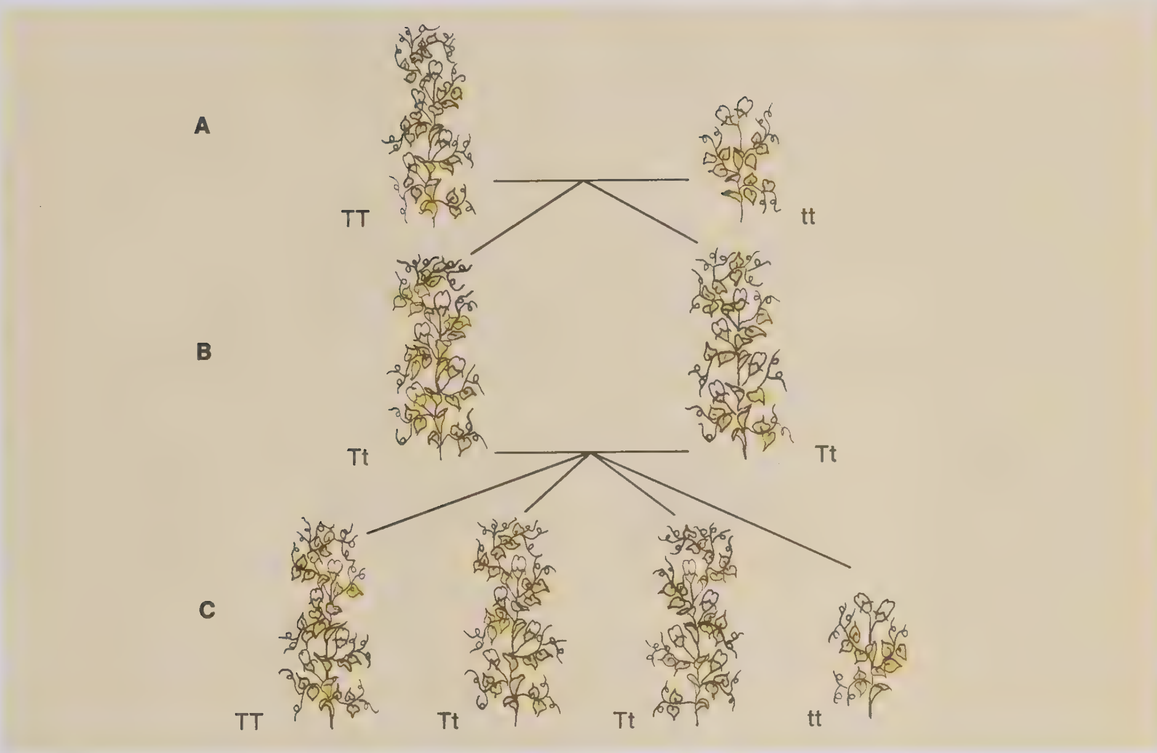


Fig. 10–2. This drawing shows Mendel's famous experiment with tall and short peas. Note that all hybrids are tall and that short plants are produced only when both genes are present for shortness.

three-fourths grew into tall plants, and about one-fourth became short plants as shown in Fig. 10-2C.

Mendel made more studies of these plants. He found that the short plants would breed true. That is, when he crossed a short plant with another short plant, the offspring were all short. He found that one-third of the tall plants (the C group in Fig. 10–2) always produced tall offspring when they were self-pollinated. But the other two-thirds of the tall plants were hybrids. When they were self-pollinated their offspring showed the three-to-one ratio of tall and short plants. What Mendel really found, then, was that hybrid parents can be expected to have about one-fourth of their offspring pure for one trait, one-fourth pure for the other trait, and that half of them will still be hybrids.

Mendel reasoned that a trait for tallness inherited from one parent hid the one for shortness which came from the other parent. The hybrid had both kinds of inheritance; but the trait for tallness was "stronger," so the hybrid plant grew tall. Mendel called the "strong" trait a ***dominant*** trait. He called the one that stayed hidden a ***recessive*** trait. There are many examples of dominant and recessive traits. In guinea pigs, for instance, black color is dominant over white color. A guinea pig looks the same whether it is pure for black or is a hybrid. In cattle hornlessness is domi-

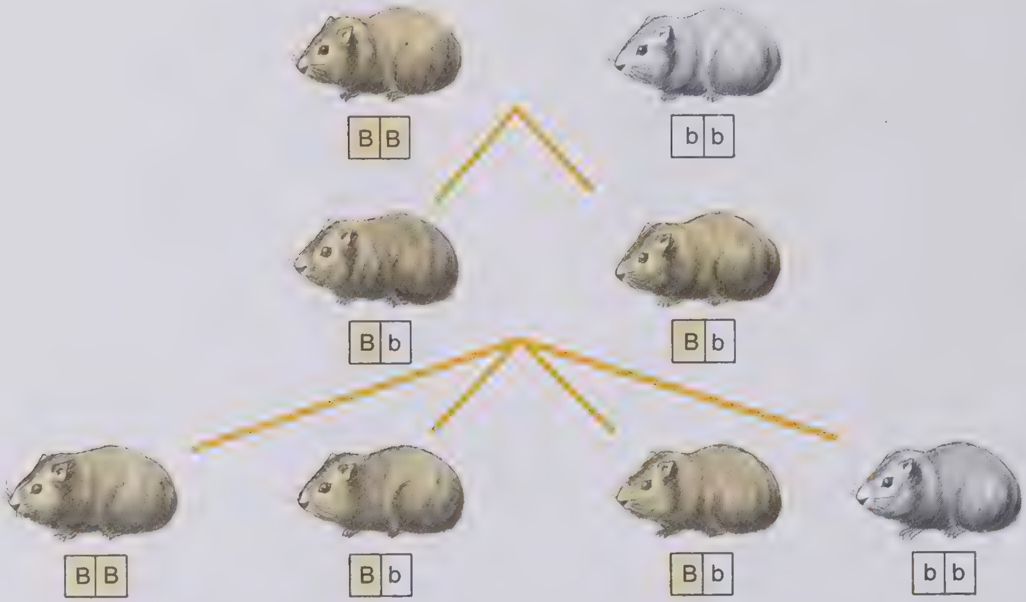


Fig. 10–3. Here we see dominance of black fur over white fur in guinea pigs. The capital letter B represents the dominant gene for black and the small letter b represents the recessive gene for white.

nant over the normal horned condition.

Understanding Mendel's results. Mendel did not know exactly why he got the results that he did. Now we can explain them, because we understand cell structure and sexual reproduction better than they did in his day. You have probably guessed already that it is the genes passed on by parents that produce the tall or short pea plants or the white or black guinea pigs. You have already read in Chapter 6, how genes are carried in chromosomes and passed on each time the cell divides. What was not explained there is the fact that each body cell in a higher plant or animal contains two of each kind of chromosome. A human body cell with its 46 chromosomes really has just 23 kinds. There are two complete sets of 23 each. One of each kind of chromosome comes

Fig. 10–4. This photograph shows chromosomes from a cell in the human body. How many of them can you count? What reason can you give for the fact that each one is double? (James L. German III, M.D.)

from one parent, and one of each kind comes from the other. Human chromosomes are shown in Figure 10–4.

In Mendel's hybrid peas, there was a chromosome with a gene in it which made the peas grow tall. This same gene in the other chromosome of that pair was a little different. It was a gene for shortness. In this situation the gene for tallness was dominant and produced a tall pea plant. But the chromosome with the gene for shortness was still there, and could be handed on to the next generation. A recessive trait shows up only when both chromosomes of a pair contain the genes for that recessive trait.

Sometimes one gene of a pair is not entirely dominant over the other. If you cross a white snapdragon with a red snapdragon, the offspring will have pink flowers (Fig. 10–5). A cross between red and white short-horn cattle will result in animals that have red and white patches of color. When a difference in genes results in a compromise like this we call it a case of ***incomplete dominance.***

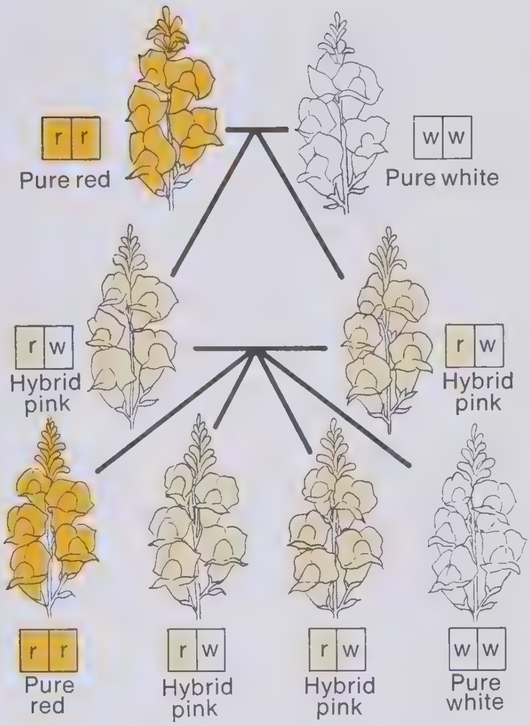


Fig. 10–5. A cross between red and white snapdragons results in pink flowers. The hybrid looks different from the pure types. This is a case of incomplete dominance.

Reduction division. Remember that mitosis is the common type of cell division. In mitosis, each chromosome is duplicated. Each of the daughter cells gets a complete double set of chromosomes. Although a daughter cell is smaller than the parent cell at first, it has the same heredity as the parent cell that produced it. And since all ordinary body cells divide by mitosis, they all have complete double sets of chromosomes. If sperm and egg cells were produced by mitosis, fertilization would result in a new individual with twice the original number of chromosomes. Do you see why? In the next generation, the number would double again, and so on. But this does not happen. Actually the sperms and eggs are produced by a special sort of cell division. It is called ***reduction division.***

A reduction division looks very much like mitosis. It is not, however, the same. In a reduction division each pair of chromosomes is separated. One chromosome of each pair goes to one cell. The other chromosome of this pair goes to the other cell. So cells formed during a reduction division have only single sets of chromosomes. This means that each cell has only half of the normal chromosome number.

Both egg cells and sperms pass

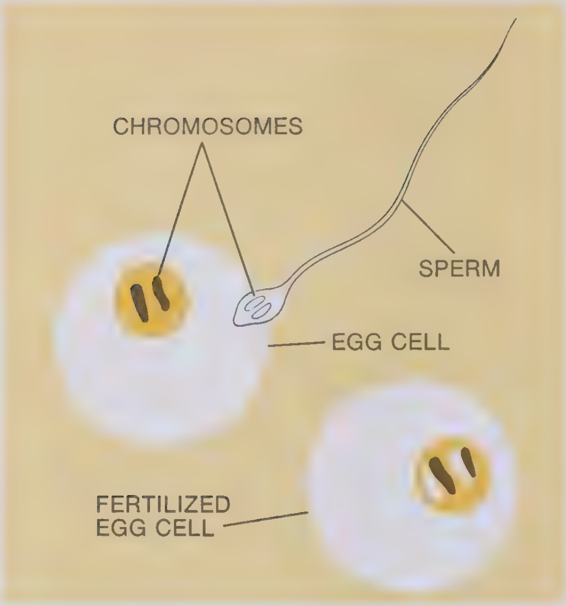


Fig. 10–6. A sperm and an egg cell each carry a set of chromosomes. This gives the fertilized egg cell two of each kind of chromosome. This drawing represents a species having only four chromosomes in each body cell.

through the reduction division. When they are mature, they have only single sets of chromosomes. Now they unite in fertilization, and a fertilized egg cell is the result. This fertilized egg cell which develops into an embryo, contains the normal paired number of chromosomes (Fig. 10–6). In each of your body cells, with its 46 chromosomes, one set of 23 (contained in the egg) came from your mother and the other 23 (contained in the sperm) came from your father.

Of the 23 chromosomes that came from your mother, it is a matter of chance which of them were ones she got from her mother and which were ones she got from her father. In other words, it is a matter of chance just how much of your heredity came from each of your grandparents. You and your brother or sister are more or less alike depending on how many of the same chromosomes you happened to inherit.

Predicting heredity. Suppose you wish to predict what the results will be if you cross two similar plants or animals. Mendel's hybrid peas are a good example to use. If we use the capital letter *T* to represent the dominant gene for tallness and a small letter *t* to represent the recessive gene for shortness, then a hybrid with one of each would be *Tt*. The *Tt* hybrid would be tall because it carried the dominant gene. These two genes would be separated during reduction division so that, in the sperms and eggs produced, there would be equal numbers carrying the *T* gene and the *t* gene. There would be an equal chance that the *T* gene from one plant would unite with a *T* or with a *t* from the other plant. Likewise there would be equal chances for the *t* from the first plant to pair off with a *T* or a *t* during fertilization. It is simply a matter of chance which sperm happens to fertilize which egg cell. A handy way to show this is to use a chart. We list the kinds of genes present in the egg cell on one side and the kinds in the sperm on the other, as shown below.

Genes in the sperm

Genes in the egg cell	T	t
T		
t		

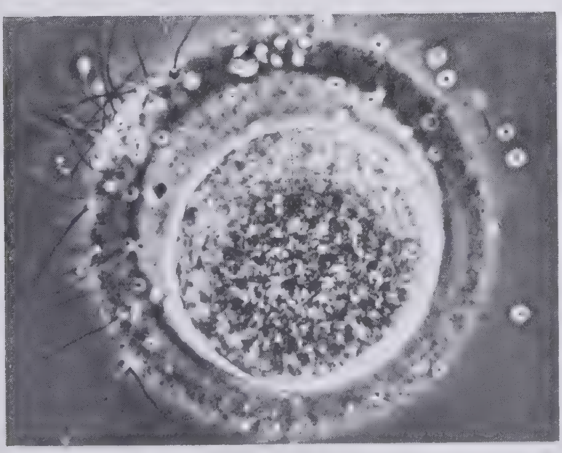
Then we simply fill the spaces in the table, by pairing each gene from the sperm with each gene from the egg cell. The completed table is shown below.

Genes in the sperm

Genes in the egg cell	T	t
T	TT	Tt
t	Tt	tt

You will notice that these results are the same as those that Mendel had in his experiments. Three of the spaces have at least one dominant gene, *T*. These plants will all be tall. One of these is pure for tall (upper left). Two others are hybrids. One space has recessive genes only (lower right). This plant will be short. So there are three tall plants and one short plant. This is the three-to-one ratio that results when two hybrids are crossed.

Fig. 10–7. A human egg cell surrounded by sperms. How many of these sperms can unite with this egg cell? How many chromosomes does each sperm carry? How many chromosomes are in the egg cell? (Dr. Landrum B. Shettles, Columbia-Presbyterian Medican Center)



There are two things you should remember. First, you cannot be sure what any offspring will be like. You only know what the chances are. In the case of these hybrid peas, there is one chance in four of producing a short plant. Second, the trait in which you are interested may depend upon more than one pair of genes. Several pairs of genes influence some traits. Human skin color, for example, is affected by at least four pairs of genes. Genes for hair color show an incomplete type of dominance. As a result many shades are possible from very dark to very light.

Boy or girl? The sex of human beings is controlled by heredity. A pair of chromosomes in the cells of females are called *X chromosomes*. In men there is only one *X* chromosome. Paired with it is a shorter one called the *Y chromosome*. In other words, females have two *X* chromosomes while males have one *X* and one *Y*. These are the chromosomes that decide what sex a child will be.

During reduction division, when egg cells are being formed, the *X* chromosomes of the female are separated. Each egg cell contains an *X* chromosome. Reduction division in sperm formation produces some sperms with *X* chromosomes and some with *Y* chromosomes. These two types will, of course, be present in equal numbers. If a sperm carrying an *X* chromosome fertilizes an egg cell then the fertilized egg cell will have two *X*

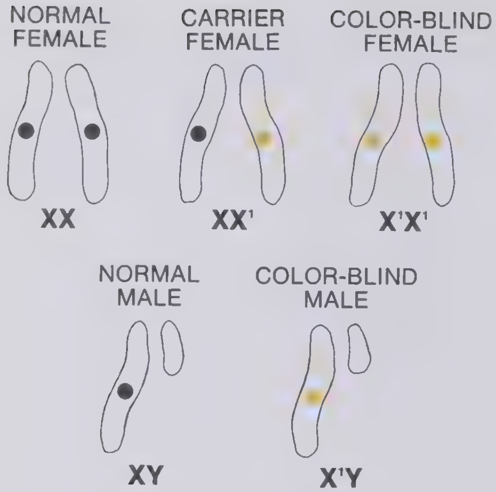


Fig. 10–8. These drawings represent the X and Y chromosomes in five kinds of people. Colored dots represent genes for color blindness. Black dots are for normal vision. Normal is dominant. Can a normal gene hide the effects of a color blindness gene in a man? Could the sons of a woman who is color blind have normal vision? Why?

chromosomes. It will develop into a female. If a sperm with a *Y* chromosome unites with the egg cell, the result is a male. The *Y* chromosome carries genes which produce male traits.

Thus, a male or female is produced depending on which of the two kinds of sperms fertilizes the egg cell. Since the two types of sperms are present in equal numbers, we can expect about equal numbers of males and females to be born. Actually, in the case of human beings, there are about 106 boys born to every 100 girls. Apparently the *Y*-carrying sperms have a slightly better chance of fertilizing the egg cell.

Sex-linked recessives. Suppose a female carries a gene for an undesirable trait in one of the *X* chromosomes. If the other *X* chromosome carries a normal gene for the same trait, and the normal gene is dominant, the undesirable trait does not show up in this female. But suppose a male carries the same harmful gene in the *X* chromosome. There is no other *X* chromosome to carry a normal gene for that trait, so the defective gene is the only one present. In this male, the weakness actually shows up. We call such traits ***sex-linked.***

Color blindness is much more common in men than in women. It is due to a sex-linked, recessive gene.

A serious sex-linked disease is called ***hemophilia*** (heem-oh-*fee*-lee-ah). It is a bleeding disease due to the fact that the blood does not clot. The victim may bleed heavily from just a small cut or bruise. Men have this disease much more often than women, because it is caused by a recessive gene in the *X* chromosome. In a woman this recessive gene may be paired off with a normal gene in the other *X* chromosome. In this case she will not develop the disease. But in a man, there is no other *X* chromosome. If a man carries the defective gene, in his single *X* chromosome, he will suffer from hemophilia. From whom does he inherit the disease?

Sex influenced traits. Not all inherited differences between the sexes are due to genes in the *X* and *Y* chromosomes. A gene in any of the other chromosomes may act differently in males than in females. The trait controlled by such a gene is said to be ***sex influenced.*** Common baldness is an example of this. The gene for baldness is not a sex-linked trait. The general body chemistry in a man is a little

different from that in a woman. This can cause the same gene to act differently in the two sexes. In a man the gene for baldness is a strong dominant one. One gene is enough to make him bald. In a woman it is a weak recessive. Even two of them will not usually cause baldness. They simply produce a growth of hair that is thinner than usual. There are many forms of human baldness. Some cause the hairline to move back a little. Others cause more baldness, and others still more. Some produce baldness earlier than others. Different patterns of baldness run in different families.

So, boys, what are your chances of keeping your hair? If Dad is bald they are no better than 50–50. Why? If Mother's father and brothers showed baldness also, your chances are not too good. Can you ever be sure ahead of time?

Remember, we are talking here about ordinary "pattern" baldness. Sometimes baldness is caused by disease. In that case a doctor may be able to stop the loss of hair. Do not waste your time going to someone who is not a genuine medical doctor. There are people who will take your money for treating hereditary baldness. This is hopeless.

How about twins? Twins may be produced in either of two different ways. First think about the normal course of reproduction. Remember that an egg cell is released from an ovary. It is fertilized by a sperm in the oviduct. Then the fertilized egg passes down into the uterus, where it develops into an embryo. Many twins are formed by a simple change in this story—two egg cells are released from the ovaries at the same time. Each is fertilized by a different sperm, and both develop in the uterus. Such twins are no more or less alike than any other two children of the same parents. They can be male and female, or they can be of the same sex. Such twins are called ordinary or ***fraternal twins.***

The other kind of twins start out as a single egg cell which is fertilized in the usual way. Then, at a very early stage in its development, the embryo splits in two, and each part develops into a complete individual. This splitting can occur when the fertilized egg has only divided once. Or it can happen later on when the embryo is made up of several cells. After the splitting, each half of the original embryo continues to live and grow. A pair of ***identical twins*** is the result. These twins look alike because they started out to be one person. Their heredity is exactly alike. They are always of the same sex.

Of course many animals produce several young at a time. Twins seem unusual to us only because in our species one baby at a time is the normal number. When animals have whole litters of young at one time, they are usually of the fraternal type. The armadillo is one animal that commonly produces litters of identical young.

Variation within a species. What do we mean when we talk about a ***species*** (*spee*-sheez)? A species is a distinct kind of living thing. House cats all belong to one species. People all belong to one species. But, as you know, each cat or each person is different from all others in many small ways. The

Fig. 10–9. Identical twins. Why are they so much alike. Can there be any differences? Explain. (Hays/Monkmeyer)

individual members of every species of living things vary in this way. We call these differences *individual variations*. You can recognize your friends because of individual variations. One person may be tall, lean, and blonde. Another may be short, fat, and brunette, and so on. There are small, long-haired cats and large, short-haired cats. Each person or each cat has his own special combination of characteristics. Look around the classroom. How many students have exactly the same shape of nose or ear or chin?

By now, you should be able to explain these variations. Remember that there are thousands of genes in the chromosomes. Many of these come in a variety of forms. For example, there is the gene that produces tallness in pea plants. Another variety of this gene produces short plants. There are genes which produce straight hair in man, but other forms of these same genes produce wavy hair and still others produce curly hair. Some genes are known to come in as many as twenty different forms. Of course, no one person has more than two of them.

Just how likely is it that two individuals would inherit exactly the same genes? You and your brother or sister have the same parents. How likely is it that both of you inherited the same chromosomes? That would depend on how many possible combinations of chromosomes your parents could produce. Think about it for a minute. Each of your parents has 46 chromosomes, but only 23 came to you from each parent. It was a matter of chance which combination of these two sets you have. It is also a matter of chance which sperm fertilizes the egg cell.

Actually, the chance of producing any one particular combination is about one in 70 trillion. This is the chance you, with your special combination of traits, had of being born. A child of your parents could just as easily have had one of the other 70 trillion possible combinations of chromosomes instead. As you see, it is not likely that there has ever been another person just like you. Nor is it likely that there will be another.

Environment. Of course the exception to individual variation is identical twins. They look alike because they have exactly the same genes. But even identical twins show slight differences. These cannot be due to heredity, so they must be due to environment. Heredity sets the pattern for growth and development of any living thing. This pattern can develop only if the environment allows it to. A tree seed has tree genes. But if it gets no water it will never be a tree. Water is a necessary part of its environment. Your genes may call for you to grow to a certain height, but unless you receive the right food you will never become that tall.

Some of your characteristics are not things you inherited. Suppose you are playing baseball, and you get cut on the ankle by a spike on another player's shoe. The cut heals, but leaves a scar. This scar is a characteristic you got during your lifetime. You did not inherit it. You got it as a result of an accident. You may have it all your life, but it will not change your genes. You will not pass it on to your children. Such traits cannot be inherited.

As you see, both heredity and en-

vironment influence the development of any plant or animal. If you want to have an interesting class discussion, you might try to decide in what ways heredity and environment influence the following traits in people: height, build, looks, intelligence, honesty, personality, health.

ACTIVITY

An example of human heredity. Your teacher will give you a small piece of clean white paper. It has been soaked in a harmless chemical called PTC and then dried. Some of the chemical is still in the paper. Chew the paper and see if you taste anything. What does it taste like? Find out how many of the students in your class can taste the PTC and how many cannot. This is a hereditary trait. You inherit your ability to taste or not taste this substance.

Let each member of the class take papers home for his family to taste. How many tasters had one parent who was a nontaster? Two parents? No parents? How many nontasters had parents in each of these groups? Try to figure out from this information whether tasting is a dominant or recessive trait. If there are not enough cases in your class for you to be sure ask your teacher for the information from other classes. Add them all together to get enough cases to base your conclusions on.

You may do the same sort of study by using the tongue-rolling trait. Some people can curl their tongue up at the edges to form a roll or tube. Others cannot. Can you? This ability is inherited. Ask each member of your family to stick out his tongue and roll it up at the edges. Write down your results. Collect these results for the whole class. Is the gene for tongue rolling dominant or recessive?

CHECK YOUR FACTS

1. **How did Mendel experiment with heredity?**
2. **What is meant by a dominant trait?**
3. **What is meant by a recessive trait?**
4. **Give some examples of dominant and recessive traits.**
5. **What is meant by incomplete dominance?**
6. **What is reduction division? When does it take place?**
7. **What percent of the offspring would show the recessive trait in each of the following crosses: Pure dominant mated with pure dominant; Pure dominant mated with pure recessive; Pure dominant mated with hybrid; Pure recessive mated with pure recessive; Pure recessive mated with hybrid; Hybrid mated with hybrid. (Use the chart method shown on pages 84 and 85. You may need some help from your teacher to get you started.)**

8. **What decides the sex of a new baby?**
9. **What is meant by a sex-linked trait?**
10. **What is meant by a sex-influenced trait?**
11. **How are the two kinds of twins produced?**
12. **How do heredity and environment influence the development of a living thing?**

CHAPTER 11

Mutation and Adaptation

Remember that the nucleus of each cell contains DNA molecules which make up the heredity units called genes. Each gene controls the production of a particular enzyme. These enzymes control all the chemical activities of the cell and these activities control the development of the plant or animal. The way a plant or animal looks depends on the structure of the DNA molecules in its fertilized egg from which each body cell is developed.

We usually think of genes as things that remain unchanged. They merely turn up in new combinations in each generation. This is true most of the time, but surprising things do happen. The genes may not always remain the same. Now and then some of them vary from their usual form, and when this happens, a new trait is the result.

The nature of mutations. Sometimes we observe the sudden appearance of a new trait. Suppose for instance that a baby is born with double thumbs. All of his ancestors had normal thumbs, but this baby is different. When he grows up and has married, some of his children have double thumbs. So do some of his grandchildren. Thus it becomes clear that a new trait has appeared and that it is definitely inherited. The big question is—what caused this new trait to appear?

The answer is simple for biologists know that one or more genes have become changed. The DNA molecules in these genes are long and complicated. They contain thousands of atoms. These atoms can be arranged in a vast number of patterns. Every time a cell divides, the DNA molecules must be duplicated. It is really not surprising that something "goes wrong" once in a while. The pattern of the atoms in a DNA molecule is changed, so it is no longer the same DNA molecule. It causes one or more new enzymes to be produced. A new trait appears due to the action of the new enzyme or enzymes.

Biologists call this new trait a ***mutation*** (mew-*tay*-shun). The new type of gene keeps on duplicating itself and producing the new trait. There has been a change in heredity. The new character is either dominant or recessive. In the case of the double thumbs we have described, it would be dominant. Can you see why?

Many people who raise plants and animals note that mutations have occurred once in a while. Traits appear that were not known to exist before.

Most of the new traits are rather minor changes. But now and then a change of much greater importance takes place.

When a gene mutates the new form may be an improvement. But in most cases it is not. Some mutations are so harmful that they cause early death in the individual. The many minor changes do little good on the one hand and cause little harm on the other.

The body of a higher plant or animal is like a complicated machine. It works well as it is. This is why the plant or animal has survived. Mutations are changes that happen by chance. Any chance change is quite likely to be harmful. If it is very harmful, early death takes place. This is the end of the mutation and it is not passed on to another generation.

Quite a few harmful mutations keep on going. This can easily happen when they are inherited as recessive traits. Suppose, for instance, that a mutation causes some physical defect. The defect is serious, but it is inherited as a recessive. Any individual who has two genes for the defect will develop the defect. This individual may die early in life. But an individual who has only one gene for the defect does not develop that defect. This individual is likely to survive and to produce offspring. Some of these offspring get the defective gene. So the defective gene that is recessive may be passed on from generation to generation. Now and then a descendant has a double dose of the defective gene and develops the defect.

Causes of mutation. Naturally we wonder what causes mutations. We cannot be sure about the causes, but we do have ideas about some of them. The natural vibrations in the molecules, for instance, may produce some mutations. Molecules are always in motion. This may cause a few atoms to line up wrong in the DNA molecules.

Fig. 11–1. The number of this man's fingers results from a mutation in one of his genes. Do you believe this trait will hurt or help him? Will it affect the length of his life? (United Press International Photo)

Certain chemicals can cause mutations. The chemical substance damages the cell, but not enough to kill it. If genes are changed, mutation is the result. Such things as formaldehyde, mustard gas, and creosote can produce mutations. These materials would not ordinarily enter living cells, but very likely there are chemicals in natural foods which can cause mutations. We should be especially careful when new chemicals are used. Insecticides, food preservatives, and drugs need to be thoroughly tested before they are sold to the general public.

Radiation, such as X rays, can produce mutations. There is always some radiation present on earth. It comes from outer space in the form of *cosmic rays*. Another form called *gamma rays* is produced by some of the elements found in rocks and soil. All of this *background radiation*, as it is called, is thought to be responsible for about 10 percent of the mutations that commonly happen in living things. For man this percentage may be higher. Obviously, X rays or nuclear energy should not be used carelessly or they may add to the number of mutations occurring in man.

Suppose a doctor X-rays a broken arm. This may cause mutations in a few cells in that arm. But there is no lasting damage. There are many millions of cells in an arm, and it would not matter if a few were actually killed. The X-ray picture shows the doctor just how the bone is broken, so that he is able to do a much better job of setting it. But suppose X rays cause mutation in the cells of the ovaries or the testes. These cells produce the sperms and egg cells that develop

Fig. 11–2. This pure white albino kangaroo may or may not live as long as his fellow animals. Do you believe his albinism will help or hinder his survival? (Burrows/LIFE Magazine © 1963 Time Inc. All rights reserved.)

into new individuals. A mutation in one of these cells might be passed on to every cell in the body of the new individual. It is very important that these reproductive organs not be exposed to X rays.

When a nuclear bomb explodes, a very large amount of radiation is given off. People not quite close enough to be killed by a bomb blast may still receive a good deal of radiation. This might result in an increased number of mutations. It might produce more genes that cause defects.

What becomes of mutations? As we have said, most mutations are harmful. If new ones keep forming in each generation, you might think that finally every species of living thing would die out. To see why this does not happen, turn back to Chapter 7 where we explained the advantages of sexual reproduction. Any animal or plant that inherits genes which greatly handicap it will probably die before it reproduces. That is the end of those genes. They will not be handed on. If a living thing is handicapped just a little, it may not die right away, but it probably will not reproduce itself as well as the healthier members of its species. There will be fewer and fewer of its kind of genes as time goes on.

In any species, then, a number of new mutations turn up in each generation. At the same time, about the same number of old mutations is lost through death. Thus the number of harmful genes present in the living population remains about the same at all times. If anything should increase the number of mutations being formed then there would be more harmful genes to be eliminated. The death rate would increase. This effect would not show up right away because many of the mutations would be recessives. It would take time for them to be eliminated through death.

There are many examples of harmful mutations. We have already mentioned the recessive sex-linked gene for hemophilia, which causes bleeding. This gene appears as a new mutation every once in a while. About 10 percent of our population is nearsighted. This nearsightedness is hereditary, and no doubt it started by mutation. An ***albino*** (al-*by*-no) animal has no coloring in its skin or eyes. White mice and white rabbits with pink eyes are albinos. The albino trait is due to recessive genes. Wild albinos are soon killed, because they do not see very well, and they are easily seen by their enemies. Their genes die with them but new genes for the albino traits keep appearing through mutation.

Adaptation. You already know that each kind of wild animal or plant is well fitted to live in some particular kind of place. We say that each living thing is ***adapted*** to its way of life. The surroundings in which a plant or animal lives are called its ***habitat*** *(hab*-uh-tat*)*. Each living thing is adapted to live in some particular habitat.

A squirrel, for instance, is well adapted to a woodland environment. It has curved claws and muscular legs for climbing. It has a long tail for balancing. Its teeth and digestive system fit it for eating foods such as nuts, acorns, buds, and bark.

Think what a different set of adapta-

tions a fish has! A fish could not live in the trees, nor could a squirrel live in a lake. Each is adapted to a particular kind of life. These adaptations are mostly inherited. The genes of a squirrel adapt it to the trees. The genes of a fish adapt it to the water. Any mutation which causes a living thing to be less well adapted to its surroundings is a harmful mutation. A mutation which makes the living thing better adapted is helpful. Such a helpful mutation aids the animal or plant to live longer and reproduce more often. Thus, new helpful genes become more and more common.

Now we can see why living things are so well adapted to their surroundings or environments. Any mutation that makes them better fitted to survive becomes "standard equipment" for the species. It becomes part of the ***gene pool.*** This gene pool is made up of all the genes found in any species of plant or animal. It contains genes that produce helpful traits. It also contains genes that produce harmful traits. But the harmful genes tend to be lost from the gene pool. Plants or animals that have such genes are less likely to survive and produce offspring.

The squirrel we were just speaking of was the ordinary tree-climbing type. There are also ground squirrels, which live in open country and dig holes to hide in. Suppose a ground squirrel had a mutation which gave him curved, slender, pointed claws like those of the tree squirrel. Such claws are fine for climbing trees, but they are not good for digging holes. This would be a "bad" mutation for the ground squirrel. It could not dig a good hole to hide in, so it might soon be eaten by some hawk or fox. If a tree squirrel inherited a mutation that gave him straight, strong, digging claws, this squirrel, also, might soon be caught and eaten. The same gene that is "good" for one animal may be "bad" for another, depending on whether the gene fits them for life in their particular habitat.

Fig. 11–3. Left: a Holstein cow which is a good dairy type. Right: a Hereford which is a good beef type. Both of these breeds are descended from the same wild cattle ancestors. How did they become so different? (Holstein-Friesian Association; American Hereford Association)

All offspring do not survive. All species of living things produce more young than can possibly survive. A pair of squirrels has several young squirrels each year. Mice have several young every few months. A pair of robins produce about eight young birds each year. At this rate of increase there would soon be too many squirrels, mice, robins, and other animals. There would not be enough food available for this increase in numbers. A single tree often produces thousands of seeds. There is not enough space for all of these to grow.

Most young plants and animals die before they grow up. They fail to obtain enough food or living space. Often they are killed by their natural enemies. Those that are best adapted to their environment are most likely to survive. They will be best able to obtain the things they need and to avoid their enemies. The individuals that are not so well adapted die out.

The well-adapted plant or animal is one that inherits genes that enable it to survive. It will probably live longer than a poorly adapted individual. It reproduces and its genes become more common in the gene pool. These genes are handed down to new generations of the plant or animal. Meanwhile, harmful genes are lost from the gene pool and especially so if they are dominant. Can you see why harmful, dominant genes are likely to be weeded out?

Natural selection. You can see, then, that the conditions under which a plant or animal lives select the genes that will survive. We call this ***natural selection.*** Natural selection works slowly, but it is very effective. It keeps the different species well adapted to their habitats. It can even help them to become adapted to new habitats.

If tree squirrels lived in a region where trees were slowly becoming less common, then any mutations which fitted them for life on the ground would be more useful. If the change from woodland to open country came slowly enough and if the right mutations appeared, natural selection might adapt these squirrels to stay on the ground all the time. They would become ground squirrels!

Conditions on the earth change. The earth is nearly five billion years old. There has probably been life on it for over half that time. During this long, long time conditions on the earth have changed over and over again.

During most of the earth's history, there has been a warm climate the world over. But every quarter of a billion years or so there has been a cold period. During these cold periods great layers of ice called glaciers have covered large areas of the earth's surface. The latest cold period started about 1,500,000 years ago and is usually called the Ice Age. Glaciers formed and melted several times. Ice covered much of the northern states and Canada until 12,000 years ago. It finally disappeared from northern Canada only about 6,000 years ago. Even today, our winters are colder than they were during most of the earth's history.

Climate is not the only thing that changes. The surface of the land and the shape of the continents have also varied from time to time. The rocks

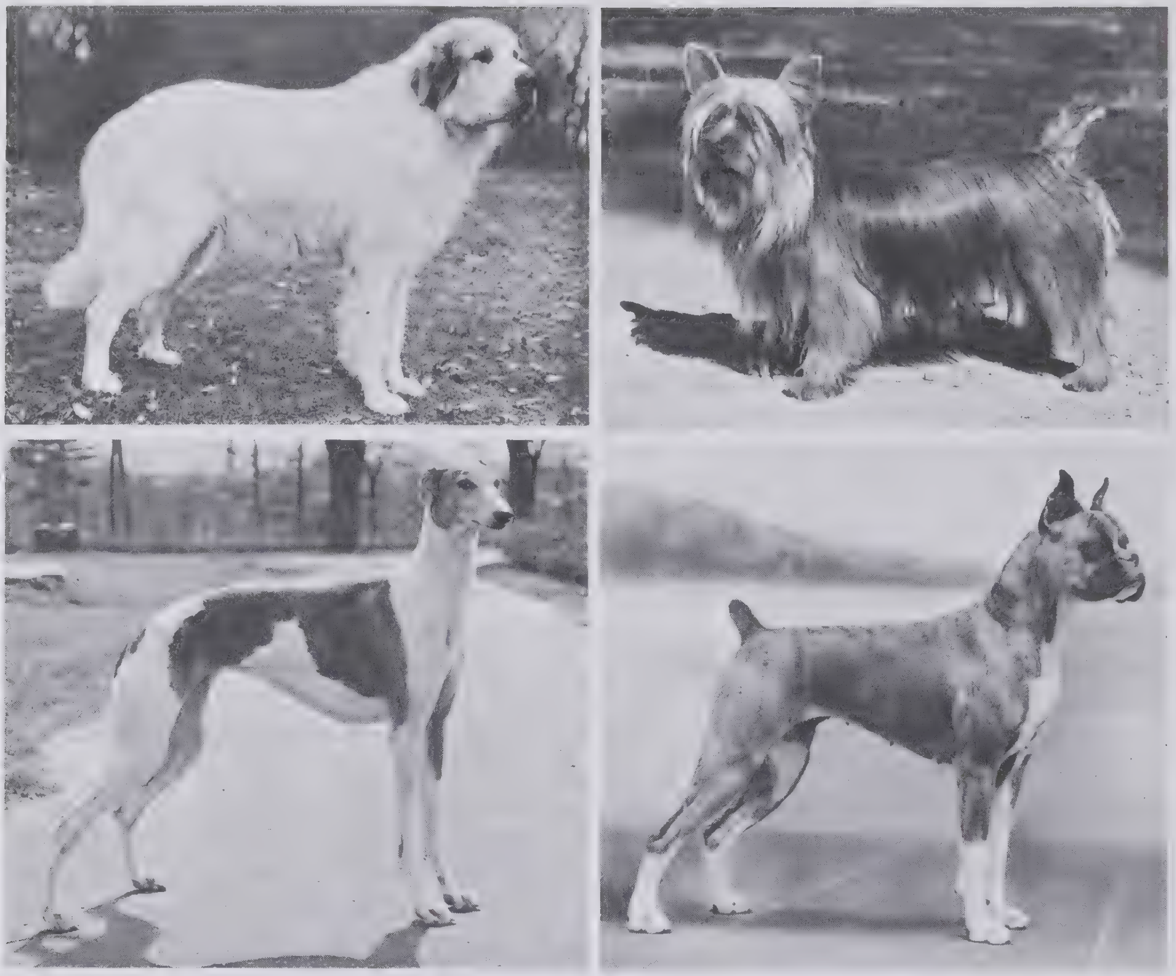


Fig. 11–4. How did each of these breeds of dogs come to look so different from each other? (Evelyn M. Schafer)

of the earth's surface may sink or rise very slowly, so that the sea comes in and covers some of the land, or land may rise out of the sea. Whole mountain ranges are pushed up and then completely worn away by the slow action of wind and rain. The sand and mud that form when the land wears down settle in the bottom of the sea and harden into rocks. Later, when the sea bottom is heaved up, these rocks become part of the land again. The land you are walking on today may have been covered by sea several times.

Through all of these changes, living things have continued to exist on the earth. Each time the environment changes in a region, many animals and plants are no longer well adapted. If the changes are great enough, many species die out completely. Others become adapted to the new conditions through natural selection. They no longer look quite the way they did before.

An interesting example of this can be seen in our farm animals. The ancestors of our cattle, for instance, were fierce, wild animals that only a skilled warrior dared to hunt. Then a few thousand years ago, brave men caught and tamed these dangerous beasts. Naturally, the wildest ones in each generation were killed and used as food. The tame ones were kept for producing calves. The ones that gave more milk were also kept. Those that gave less milk were slaughtered. Or if the cattle were being raised for beef, the ones having the most meat were kept for breeding. Man has selected the cattle having genes that produced the kind of animals he wanted.

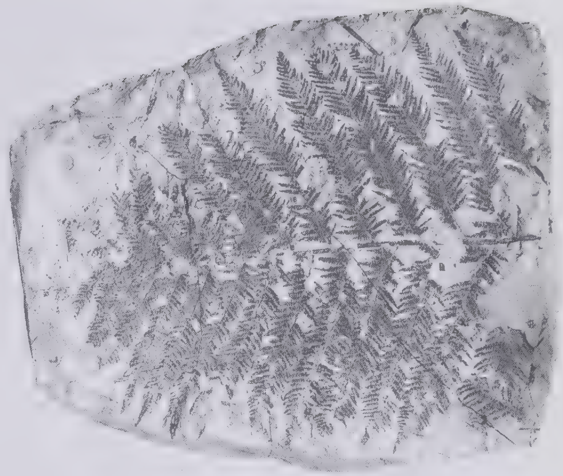


Fig. 11–5. This fossil fern leaf was part of an ancient plant that lived 300,000,000 years ago. How did it get embedded in the rock? (Courtesy of The American Museum of Natural History)

The result of this selection is the many breeds of cattle found today on our farms. They are of many color patterns. After all, man protects them from natural enemies, so a gene for coloring that can be seen easily does not matter, as it would in wild cattle. Milk cows have large udders, and often produce over 25 quarts of milk a day. This is much more than is needed for their own calves. Beef breeds have stocky, fat bodies that would slow them down under wild conditions. Selection has adapted these animals to live in a very special environment —the modern farm.

When man does the selecting we often refer to it as *artificial selection*, but it is really the same sort of thing as natural selection. Artificial selection has produced all of the breeds of plants and animals that we raise today. Since we now understand how heredity works, it is possible to develop new and better breeds more rapidly than they were produced in the past. Some new types are developed every year.

Records of past life. One very interesting branch of biology deals with the study of past life on the earth. As you have seen, mud and sand settling to the bottom of water eventually harden into rock. This process is something like the setting of cement, only it takes much longer. If some dead animal or plant lies buried in this mud, it may leave an imprint in the rock which we dig up and study millions of years later. Such records of past life are called ***fossils.*** Hard parts like bones or shells are most likely to become fossils. Softer parts are sometimes preserved. There may be a stone quarry near you in which you can find some fossils.

Scientists have been digging up fossils for many years. We now know the kinds of plants and animals that lived at various times in the past. Where the rock layers have not been

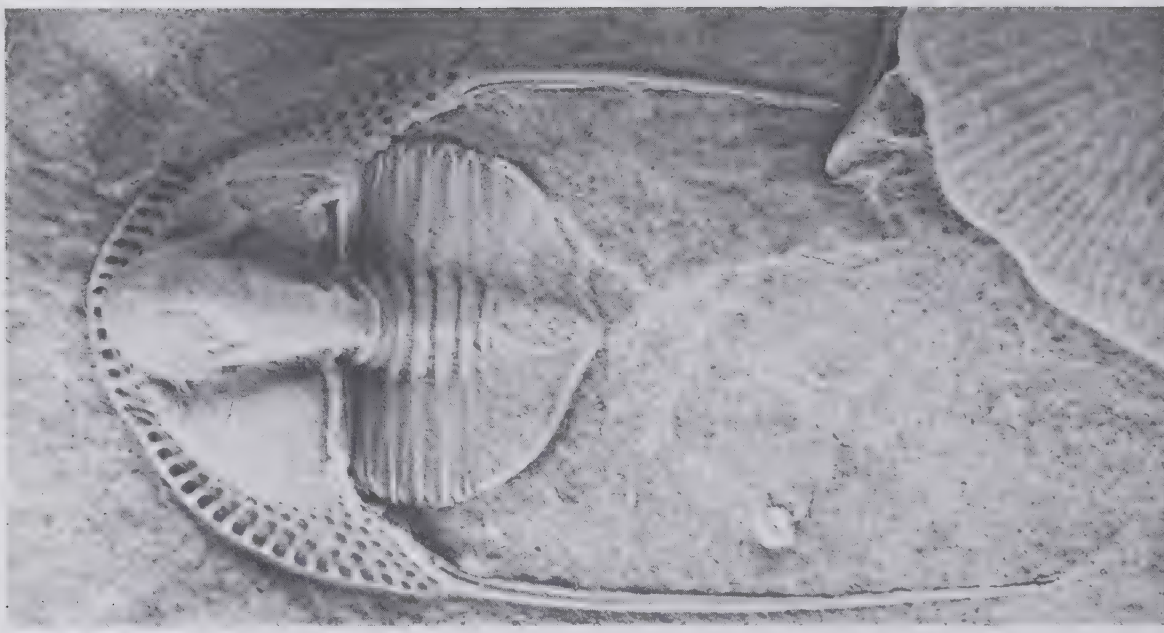


Fig. 11–6. This fossil shows the shell of a sea animal which lived millions of years ago. Was life on the earth then the same as it is now? (The Smithsonian Institution)

Fig. 11–7. This is a typical scene in a prehistoric forest several million years ago. How does it differ from a forest today? (Courtesy of The American Museum of Natural History)

folded and broken up, the lower layers are older than the upper layers. So fossils in the lower layers are also older than fossils in the upper layers.

The changing world of life. From fossil studies it appears that life began in the water. Throughout most of the earth's history, living things were small, simple forms found in the sea. By about 500 million years ago, complex, many-celled forms of life had become common. Life became abundant on the land about 340 million years ago. In each period, the forms of life seem to have been somewhat different from what they were before or after. Most scientists explain this as the result of natural selection, enabling plants and animals to become adapted to environments that have changed again and again.

In other words, the forms of life upon the earth have gradually changed. Simple plants and animals gave rise to more complex types. Certain sea plants gave rise to land plants. Certain water animals gave rise to land animals. The living things of today are descended from ancient forms which often looked very different. No doubt you have seen pictures of dinosaurs. They died out because they failed to adapt to changing conditions. Other types of animals alive at that time survived to become the reptiles, the birds, and the mammals of today.

When species change in this way the process is called ***evolution.*** The word means to develop or to change into something new. As you have seen, this process is due to a gradual change in the kinds of genes present in the members of a species. In other words, it is due to changes in the gene pool. It can be brought about by a long process of mutation and natural selection.

In this chapter, we have not gone into detail on the record of past life on the earth. Later, when we study the different groups of living things, we shall learn more about their past histories.

ACTIVITY

Making a fossil. As you know, many fossils are formed when some dead part of a plant or animal is buried in mud at the bottom of the water. This mud slowly hardens into rock. The print of the plant or animal part in this rock is a common type of fossil which we can dig up and study. If your school has a collection of fossils, study them to see what they look like. Then make your own "fossil" in the following way.

Take a saucer-sized dish (the aluminum ones that frozen pies come in are good) and coat it lightly on the inside with oil. Then lay the leaf of any tree on the bottom of the dish. Next, mix some plaster of Paris powder with water until it is about as thick as cake batter. Carefully pour this over the leaf in the dish. This is about the way mud might bury a leaf under water. It takes thousands of years for mud to harden into solid rock. But your plaster of Paris will harden in a few minutes.

After several minutes lift the plaster out of the dish and remove the leaf.

What is left in the plaster? Does the leafprint look like a fossil? Is it a fossil? Are footprints and leaf-prints in cement on a sidewalk really fossils? Remember that a fossil is a record of life in the past.

You may want to try making fossils of other objects such as shells or flowers. Would flowers be good subjects? Or, you could press your hand into soft plaster and thus make a handprint. Such a print would be about like the fossil footprints of dinosaurs which have been found by scientists.

After your plaster fossils have dried for a day or two they can be painted. You might use different colors for the fossil and for the background.

CHECK YOUR FACTS

1. **What is mutation?**
2. **What causes mutation?**
3. **Are mutations usually helpful or harmful? Why?**
4. **What is the gene pool of a certain plant or animal species?**
5. **What keeps harmful genes from becoming more and more common in a gene pool?**
6. **How does natural selection take place?**
7. **What are some of the changes that have taken place on the earth during the past five billion years?**
8. **What happens to living things when their environments change a great deal?**
9. **Why do our present-day cattle look different from their wild ancestors?**

UNIT 2 SUMMARY

Some living things reproduce asexually. But most of them reproduce sexually, at least part of the time. The basic process in reproduction is cell division. Many plants and animals develop sex cells. Cells from ovaries become egg cells. Cells from testes become sperms. A sperm unites with an egg cell to produce a fertilized egg cell.

Flowers are the reproductive organs of many higher plants. Pollen grains containing sperm nuclei are formed on their stamens. Egg cells are developed in ovaries at the bottoms of pistils. A sperm nucleus unites with an egg cell. The fertilized egg cell gives rise to a plant embryo that is enclosed in a seed. The seed will sprout when conditions of growth are favorable. Fruits are fleshy or dry parts developed from the ovaries. They enclose the seeds of many plants.

Many animals reproduce by laying eggs. The eggs are often laid and simply abandoned by the parents. But some eggs hatch within the body of the parent female. In most mammals the young develop within the uterus of the female. Before birth these young get nourishment and discharge wastes through a special structure called the placenta. Many adult birds and mammals provide care for their young.

Gregor Mendel discovered some basic laws of heredity while experimenting with garden peas. He found that when there are opposed traits such as tallness and shortness, one may be dominant and the other recessive. Understanding this helps us to predict what kind of offspring will be produced.

The members of any species differ from one another. This is called individual variation. Some of the differences are due to heredity. Others result from contact with the environment. New variations that can be inherited are called mutations. They are caused by changes in the genes of sex cells. Many mutations are minor in nature, and of no great importance. Some mutations produce greater changes. Many mutations are harmful, but some are useful.

The important molecules in genes are the DNA molecules. Each of them causes a certain enzyme to be produced. The enzyme, in turn, determines how the new individual will develop. Useful mutations tend to remain in the gene pool of a species, but harmful mutations tend to be lost from the gene pool. Through natural selection a species keeps adapted to its surroundings. We use a similar process called artificial selection to develop better types of garden plants and domesticated animals.

The earth has a very long history. Its environment has changed many times in the past. During its long existence many species have failed to survive. Others have become adapted to changing conditions of life. Plants and animals have changed greatly through the ages.

UNIT 3

Living Things In The Environment

This unit deals with living things in relation to everything around them. How are they affected by light, heat, cold, and altitude? How do soil, air, and water affect them? How do living things influence each other? There are scientists who spend their entire careers studying these types of questions. This unit will give you some of the answers they have discovered. It will also show how this information can be put to work. The whole topic of conservation is simply a matter of applying such knowledge to the practical problem of managing our natural resources wisely.

CHAPTER 12

The Nonliving Environment

You will remember that the surroundings in which a plant or animal lives are called its *environment*. In this unit you will learn something about the relationship between living things and their surroundings. If you think about it a moment, you will realize that no living thing can exist even for a few seconds without being affected by its environment or without affecting its environment. If you do not believe this, just try holding your breath while you read the rest of this chapter! Air is part of your environment. It affects you by supplying the oxygen you need. You affect it by removing some oxygen from it and adding some carbon dioxide to it. In what other ways do you and your environment affect one another? For example, think about the food you eat.

The environment is everything that surrounds or affects the individual. This includes such nonliving things as light, heat, water, soil, air, and pressure. It also includes all the other living things in the region. They certainly affect one another. These relationships become complicated at times. In this chapter we shall study the nonliving environment and in the next the living environment.

The earth's environment. To begin with, let us think about the earth as a whole. The earth is the home of plants, animals, and man. What sort of an environment must these living things have if they are to succeed on the earth?

First, the environment for living things must contain *water*. Protoplasm is made up largely of water. The other molecules in this living material can only meet and react with each other if they are dissolved in a liquid. There is probably no other liquid in the universe that can take the place of water in living things.

Second, the environment must contain a variety of *chemical elements* in order to form the complex compounds found in protoplasm. The most important of these is carbon. It holds the other elements together in such important materials as carbohydrates, fats, proteins, and nucleic acids. Carbon compounds like glucose, oils, fats, and proteins must be present if life is to exist. The other elements found in protoplasm can be obtained from the mineral salts which are present in water or in soil.

Third, *temperature* is an extremely important part of the environment of

Fig. 12-1. The moon. What conditions would be needed for life on the moon? (National Aeronautics and Space administration)

living things. To support life, water must be in the liquid form, at least part of the time. If the earth were too near the sun all the water on it would boil and turn into steam. If it were too far from the sun, water would be frozen all of the time. Thus, temperature must be the right degree for the type of environment required by each living thing.

Fourth, living things need a steady supply of *energy* in their environment. As you have learned, this comes to the earth in the form of sunlight. Green plants absorb this energy during the process of photosynthesis. Other plants and animals get their energy from the food made by this process.

So you see what a very special sort of place the earth is. It is large enough. It has enough of the right compounds. It is the right distance from the sun so as to receive a steady supply of sunlight. Conditions on the other planets of our solar system are not the same. But there are other suns and probably planets in the universe. Some far distant planets may be like our earth.

These materials and conditions for life are not present in equal amounts on all parts of the earth. It makes a difference to living things what part of the earth they live on. Suppose we take water and see how it is distributed over the earth.

The water cycle. Most of the earth's water is in the oceans. When sunlight warms the surface of the sea, some of the water evaporates. Heat energy is needed for evaporation, and the sunlight supplies this energy. Heat from the sun also supplies the energy that makes winds blow. Cold air is heavier than the same volume of warm air. Whenever the sun heats the air in one place, heavier, cooler air comes flowing in under the lighter warm air, causing it to rise. These air movements are what we call wind.

Warm, moist air from the sea may be blown over the land. It may move upward over mountains, it may move hundreds of miles northward to cooler regions, or it may be forced upward over a mass of cold air. In these cases, as the air is cooled clouds form, and rain falls. This happens because warm air can hold more water vapor than cold air can. If it is cooled enough, some of its water vapor will turn back into liquid. You can see this happen when cold windows become misty in a warm room. Clouds are simply masses of very tiny drops of water drifting in the air. When the water in them

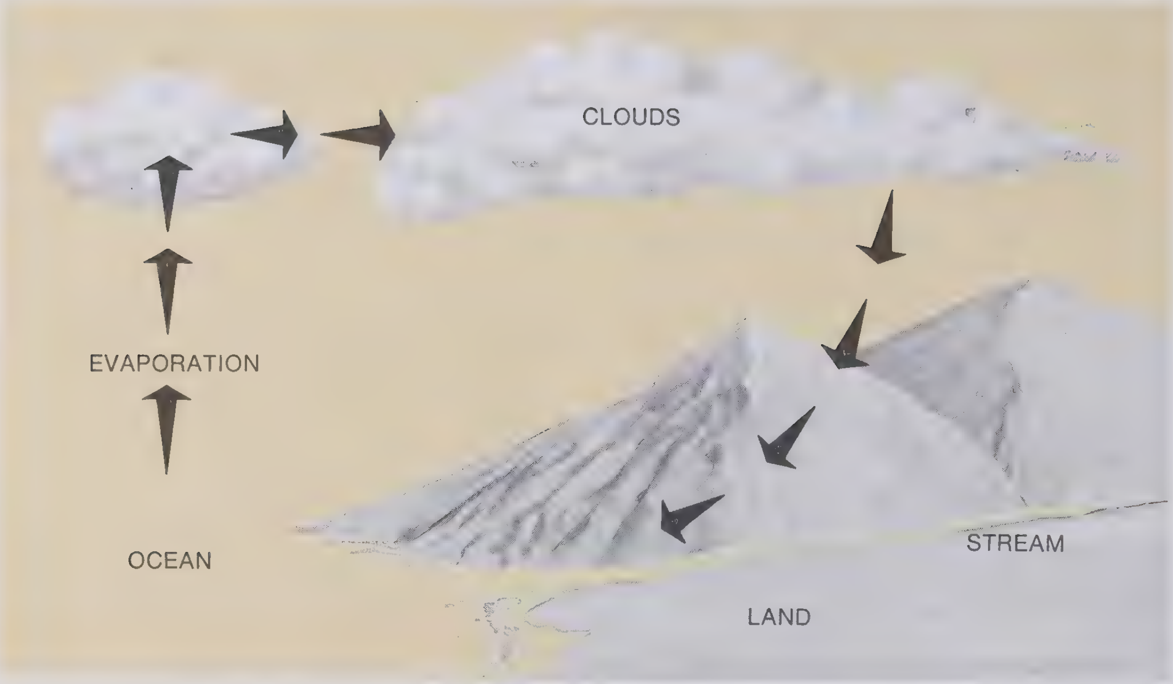


Fig. 12-2. The water cycle. How does water get on to the land? How does it return to the sea?

Fig. 12-3. What adaptations enable these plants and animals to live in water? What changes in their structures would be needed if they were to live on land? (Courtesy Carolina Biological Supply Company)

forms big drops, the drops fall as rain.

Thus the sun provides the energy for movement of water from the sea to the land. If this movement of water did not exist, there could be no land life. What happens to the water that falls on the land? Some of it runs off into rivers and back to the sea. Some soaks into the ground, where it may be taken in by plant roots. Some evaporates from soil and from leaves. This water may fall again as rain. Water sinking deeply into the ground will flow out into a valley and form a spring, lake, or stream. Eventually all water returns to the sea.

Since water starts in the ocean and returns to the ocean, we call this circulation of water the ***water cycle.*** A cycle is any situation in which something keeps repeating itself, or going in circles. As you can see, the water cycle is very important to all life on land.

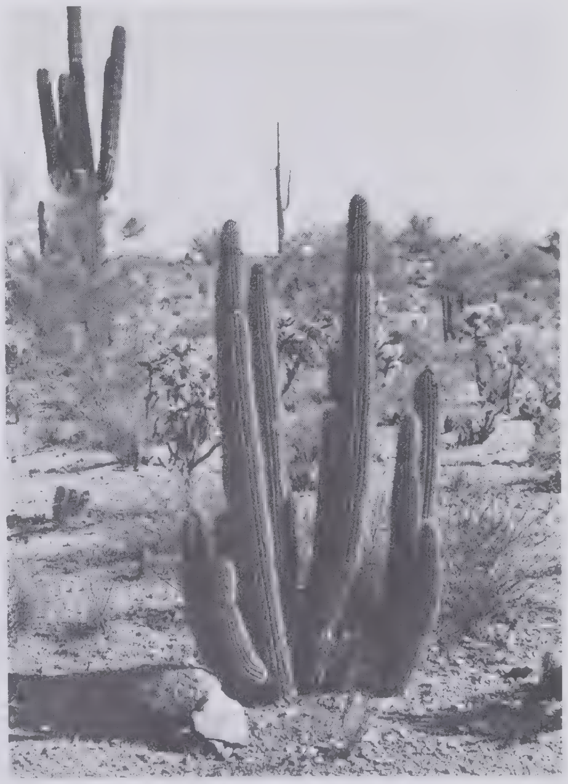
The effects of water supply. Remember what you learned in Chapter 11 about adaptation. Each kind of living thing is adapted to live in a particular kind of environment. Now we shall see how the water supply affects the kinds of life found in different environments of the world.

Many living things are adapted to make their homes in water. Some of them live at the bottom of the sea. Some live in more shallow water while some drift or swim near the surface of the sea. Others live in fresh-water lakes, ponds, or streams. Each of these environments has different conditions of life and each contains different kinds of living things. These living things have become adapted to exist under the conditions of that environment.

On land there are many variations in the amount of water available. Some living things need more water than others and certain species can live in environments where others might die. If there is plenty of rain, trees will grow. Forests usually cover the land on every continent wherever rainfall is abundant.

Where there is little rainfall, the land usually becomes a *desert*. Plants and animals that live in the desert must become adapted to this type of environment which has very little water. Some desert types like the cactus plants store water in their

Fig. 12-4. A desert. Why is there so much bare ground in the desert? How are the plants able to live in such an environment? (Phoenix, Arizona Chamber of Commerce)



thick stems and have very small leaves. Some other desert plants have long roots that reach far down to more moist soil. Various desert animals get water from the foods they eat. Many of these animals appear only at night when it is cooler than during the day. During the hot daytime they stay in their burrows where it is cooler and hence they lose much less water to the air. Small desert flowers spring up quickly after a rain, form seeds and as soon die. Their seeds will grow only when rain falls again in the desert—perhaps months or even years later.

What about regions with some rainfall but not enough for trees to grow well? There is a large area like this between the Rocky Mountains and the eastern forests. This is an area of natural *grassland*—the great plains and prairies of North America. In all continents there are similar grasslands in the fairly dry regions between the forests and the deserts. These include the *steppes* of Asia, the *veldt* of Africa, and the *pampas* of South America. Grasses grow well when there is water. Their tops die down during the dry spells, but the underground parts remain alive and send up new shoots when rains come again. Sheep and cattle are raised on such lands.

Other cycles in nature. The water cycle is not the only cycle in nature. You already know how plants take in carbon dioxide and give off oxygen during photosynthesis. You also know how both plants and animals take in oxygen and give off carbon dioxide during respiration. This is another cycle. The same atoms are in the air and in

Fig. 12-5. What conditions of the environment makes this area a grassland rather than a desert or a forest? (USDA—SCS Photo)

the sea part of the time and in protoplasm part of the time.

As you know, living things also take in mineral substances to supply them with the elements needed to build protoplasm. Sea and fresh-water plants absorb these minerals from the water they live in. Land plants absorb them through their roots from the soil. Animals obtain minerals mostly from their food. Here again is a cycle. An element may be in water or soil as part of a dissolved mineral salt. Then it is taken in by a plant and becomes part of its protoplasm. When the plant dies, decay returns the element to the water or soil once more as part of a mineral salt.

Air and soil as parts of the environment. *Soil* is important to land life as a source of water for plant roots and also as a source of minerals. Good soil is rich in minerals and is able to hold water well. Such soil will support more plant life than poor soil. Poor soil contains few minerals and does not hold water well. Very sandy soils are an example of this.

Water evaporates quickly from sandy soils and is lost. Some pines and oaks are adapted to dry conditions, so you will often find them growing on sand. Maple and elm trees need more water, so they have to grow somewhere else. You see, then, that the kind of soil in a region will have a great deal to do with the plants and animals that can live there. In Chapter 15 you will learn about the structure of soil.

The *air* is an important part of the environment. It supplies land life with oxygen and carbon dioxide. The air is also the source of the nitrogen used by all living things to build protoplasm. We shall study the nitrogen cycle when we study the bacteria. The air is also the carrier of moisture that falls as rain. Air is important even to water life. Oxygen and carbon dioxide from the air dissolve in the waters of lakes, streams, and oceans. Oxygen and carbon dioxide can also pass from water into the air.

Temperature and living things. Water supply is not the only thing that varies over the earth. There is also a great range in temperature, and each living thing is adapted to a certain temperature range.

Land animals and plants have the greatest temperature problem. On land, temperatures are much more changeable than they are in the water. Winter readings may be far below freezing. The same region may have high summer heat. Birds and mammals are the only animals that stay active in the really cold weather.

Fig. 12-6. A forest. Why do trees grow in some areas and not in others? (Grant Heilman)

They are adapted to the cold by being ***warm-blooded.*** This means that they oxidize their food so rapidly that the energy produced keeps their bodies warm all the time. Even when the weather is very cold, a bird or a mammal keeps a warm inside temperature, and its protoplasm can remain active.

Other forms of northern land life must remain inactive during the winter. In trees and other higher plants, liquids flow slowly in the vascular tissue; photosynthesis may stop; ice crystals form among the cells. All life functions slow down. ***Cold-blooded*** animals, whose inside temperature changes with the outside temperature, must find protected hiding places. Many of them simply die but leave eggs that hatch when warm weather returns. Some frogs burrow down in the mud on the bottom of ponds. Here they lie through the cold winter months. Their blood flow slows down greatly. They get a little oxygen through their skins—enough to keep them alive. They use up the excess fat which was stored in their bodies during warm weather. This condition is called ***hibernation*** (hy-bur-*nay*-shun).

Even some of the mammals hibernate. Woodchucks (also known as groundhogs) and ground squirrels are good examples of this. When they hibernate in burrows, mammals avoid the winter cold. In addition, they live through a period when food is not to be found above ground. What do birds do when their food supply disappears?

When a lake freezes over, fish still swim under the ice. There the temperature stays at about 39° F all winter long. Northern fish can withstand this temperature and remain active. So can many of the water insects and worms. But if the dissolved oxygen is

Fig. 12-7. A tundra scene. The stunted, stubby plants grow where it is too cold for larger plants to mature. (John Marr)

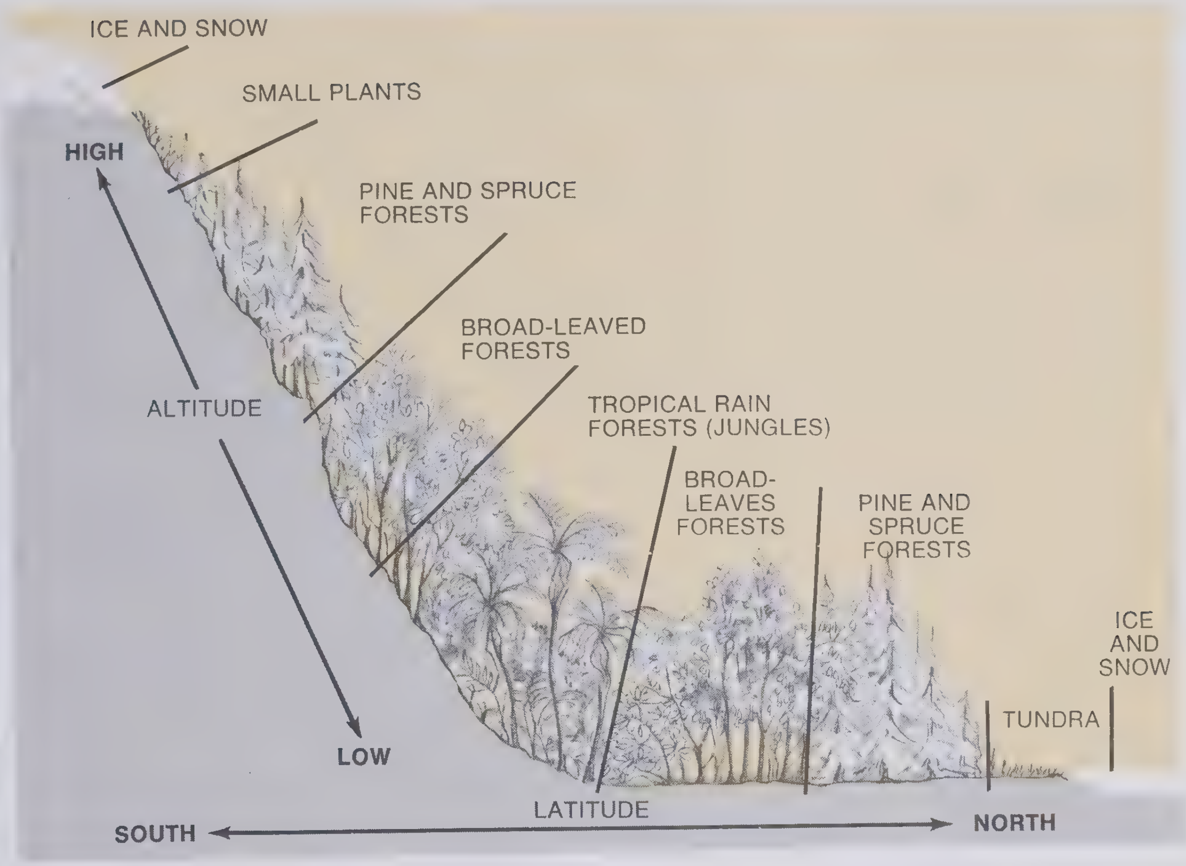


Fig. 12-8. "Changes in altitude have the same effect as changes in latitude". What does this statement mean? Where could you go to see this effect?

used up, ice prevents more oxygen from entering the lake from the air, and the fish die. This is called a *winter kill*. Winter kills are more common in shallow lakes because the smaller amount of water stores less dissolved oxygen. They are also more common in years when snow covers the ice all winter. Remember that there are green plants in the lake, and snow shuts out the light. Otherwise the plants might produce some oxygen.

Most palm trees can stand no freezing, so they grow only in the warm tropics. Maples and oaks grow best where the temperatures range from fairly cold in winter to fairly warm in summer. Canadian spruce forests are able to stand freezing conditions for about half of the year. Notice that all varieties of forests grow only where there is ample rainfall. But the kind of forest depends on the temperature.

The regions in the far northern parts of the world are too cold for trees. These are the ***tundra*** areas of northern Canada, Alaska, and Siberia. The tundra is land which is covered by small, stunted shrubs, grasses, sedges, and lichens. It has the look of

a wide, bleak, open plain. Only the surface layer of soil thaws in the summer. The deeper soil stays frozen the year round.

Altitude and living things. As you know, the higher the altitude, the colder the temperature. In climbing a mountain you see the same change in climate as you would in going north, but the effect shows up much more rapidly. In an afternoon's drive up into the Rocky Mountains or the High Sierra's, you can pass from grassy plains or from broad-leaved forest up through pine forest, spruce forest, fir forest, and out on to the open tundra. Moving a few thousand feet higher has the same effect as going thousands of miles north.

Light and living things. Light is absolutely necessary for life as we know it because light is the source of radiant energy for photosynthesis. Without light from the sun, there could be no food production by green plants. This means that green plants can only live close to the surface of the earth. They cannot live underground or in the deep sea. Animals live in these environments, but their food comes from living things that live in the light. Enough light for photosynthesis may reach a little over two hundred feet down into clear water. Below that level, green plants cannot live. The food of deep sea animals comes from plant and animal materials which sink downward from the surface. Some of the deep sea animals live as much as seven miles below the surface. There is no sunlight in such an environment.

ACTIVITY

Temperature and rate of Growth. Soak radish seeds in water for a few hours and then plant them in trays of moist sand or soil. Keep one tray in the freezer, one in the refrigerator, one in the room, and one in an incubator at about 100°F. Keep a record of when the new plants appear above ground. Which ones grow a half inch high first? Second? Third? Last? Would temperature have the same effect on all seeds? Test several others to find out (oats, squash, and beans would be good ones to try).

See if you can plan similar experiments to show the effects of light and of moisture upon living things.

The importance of water to living things. Peel a potato and cut it into thin slices. Weigh the slices together, and mark down the result. Now put the potato slices in an oven or on a radiator, and dry them out as much as you can. Actually, you probably will not get all of the water out of them in this way. But you may come fairly close.

After the potato slices are dry, weigh them again. Compare the weights before and after drying. How much weight has been lost? Was it more than half of the first weight? What does this activity tell you about the importance of water in living things?

CHECK YOUR FACTS

1. What makes light very important to living things? Do all living things need the same amounts of light? Explain your answer.
2. Explain the water cycle. (Use a drawing if it will help.)
3. What general type of plant life covers the land in a wet region? In a fairly dry region? In a very dry one?
4. What things does soil supply to living things?
5. How can soil influence what grows in an area?
6. What is supplied to living things by the air?
7. In what ways can heat be important in determining what plants and animals live in a region?
8. What are two reasons why animals hibernate?
9. What is meant by cold-blooded and warm-blooded? What advantage is there in being warm-blooded?
10. What causes winter kills in lakes?

CHAPTER 13

The Living Environment

For each living thing, other living things are a part of the environment. Living things affect one another in many ways. One interesting way to discover how they are related to one another is to see how they obtain their food. All living things need food, and many of their adaptations have to do with food-getting.

The food groups. We can group living things according to how they obtain their food. The most important food group is made up of the ***producers.***

These are mainly the plants with chlorophyll. Go outdoors in the country on any spring day and look around you. Unless you live in a desert, you will see green wherever you turn—green grass underfoot, green tree leaves overhead, green crop plants on the plowed fields. This green plant tissue is using the energy of sunlight to make food. In the sea, the same thing is going on. Seaweeds and tiny drifting sea plants are all making food. **This food that green plants make supplies the whole living world with the materials and energy needed to maintain life.**

All of the other food groups come under the general heading of ***consumers.*** They consume, or use, food which was first made by green plants. All of the animals are consumers and so are the fungus plants, such as mushrooms and molds. Many bacteria are also consumers. These fungi and bacteria do not have chlorophyll, so they must obtain their food ready made.

The largest food group among the animals is made up of ***plant eaters.*** Deer, antelope, meadow mice, grasshoppers, and elephants are a few kinds of plant eaters. Some fish and other sea animals are also plant eaters. Plant eaters do not usually have much fighting ability. After all, grass does not fight back. But the plant eaters need the kind of teeth that can grind up coarse plant foods. They also need a digestive system which is able to handle such food. Nearly all of our common farm animals are plant eaters. These animals use the plants they eat to produce meat and milk.

Another food group is made up of the ***flesh eaters.*** Wolves, tigers, weasels, ground beetles, robber flies, pickerel, and trout are a few examples of flesh eaters. Flesh eaters need to have teeth, claws, or other weapons

to catch and kill the animals they use as food. Some flesh eaters do not kill their own meat. They feed on the bodies of any dead animal they may find lying around. Vultures and blowflies are examples of this. We can call them ***scavengers***.

There are some animals that will eat many kinds of food, both plant and animal. Chickens, for instance, will eat green leaves of grass or clover. They will eat all sorts of seeds, like corn or wheat. They will also eat insects, worms, and even meat, if they can get it. Such an animal can be called a ***variety eater***. Other variety eaters include rats, bears, pigs, crows, goldfish, house mice, and man.

Parasites form another food group. A parasite feeds on another form of life, unually without killing it. The parasite lives right on or in the animal or plant it feeds on. This animal or plant is called its ***host***. Lice are parasites. They are little insects that ride around on some larger animal and suck its blood whenever they get hungry. Fleas, ticks, and tapeworms are other examples of parasites. Not all parasites are animals. Fungi are sometimes parasitic, especially on plants. Wheat rust, for instance, is a disease of wheat. It is caused by a mold-like fungus growing on the wheat plant. When people become sick with diphtheria or pneumonia it is because bacteria are living as parasites in their bodies.

Many of the bacteria and fungi are not parasites. They are mostly the type of consumers that we will call the ***decomposers***. Decomposers cause any dead plant or animal material to break down and decay. You have seen how wood, leather, cloth, meat, leaves, and many other things decay. They seem to disappear completely. Actually they have been used as food by decomposers. Usually you do not see the decomposers that cause the decay. They are too small. Often they are one-celled bacteria. Sometimes larger forms like mushrooms or molds cause the decay. Then you can see them. These decomposers digest the food first. Then this food soaks into their cells and is used up. When they are finished there is nothing left but water, carbon dioxide, and simple mineral salts. The energy in the food material is also used by the decomposers.

Food Chains. As you know, food that was first made by plants may be eaten by plant eaters. Plant eaters are eaten by flesh eaters. Flesh eaters may be eaten by other flesh eaters. These die and may be used for food by the scavengers. Meanwhile, some of these forms are fed upon by parasites. Whenever food is passed along in this manner we have what we call a ***food chain***.

Here is an example of a food chain. Grass plants make food. Grasshoppers feed on grass. Frogs eat grasshoppers, and garter snakes often eat frogs. Hawks sometimes eat garter snakes. The hawk is at the top of this food chain. There is more grass than there are grasshoppers, more grasshoppers than frogs, more frogs than snakes, and more snakes than hawks. This must be true because each member of the chain oxidizes some of the food, so that there is less and less of the material left as it is handed along in the chain. If any plant or animal in the food chain dies it will probably decay. Waste material from the living ani-

Fig. 13-1. A food chain. What does the sun have to do with this? What do you think becomes of the hawk when it dies?

mals will also decay. So all food which is made by the producers is finally used up. It is used partly by the green plants and partly by the animals and decomposers in the food chain. Can you think of a food chain with man in it?

Cycles. Study Figure 13-2. It shows the food relationships we have just been talking about. How does it also illustrate the cycles we studied in Chapter 12? Carbon dioxide from the air is combined with water and mineral salts from the soil to form food and living matter. This is the process of photosynthesis. Respiration and decay break down these materials and return them to the soil and air. They are used over and over again.

Energy does not go through cycles. It comes into the living world as sunlight. It is changed into chemical energy and stored in the food molecules. Each member of the food chain gets some of this energy and uses it to carry on its life activities. Finally the energy is changed into heat, which passes off into the surrounding environment. This heat finally radiates off into outer space.

Hunter and hunted. The process of eating and of being eaten takes place

all the time. You can easily see, then, that living things do influence each other in many very important ways.

Flesh eaters are said to be ***natural enemies*** of the plant eaters. Frogs are natural enemies of insects. Snakes are natural enemies of frogs and mice. You may think that natural enemies are harmful to their victims. Certainly it is very harmful to any animal to be killed and eaten. But flesh eaters may actually be of benefit to the kind of animal they prey on. To see why this is true, let us suppose that a plant-eating animal such as the deer, had no natural enemies. If the deer had no natural enemies, too many of the animals would live. Soon there would not be enough food for all of them. Food plants would be killed. Then many of the deer would die. The few that lived would be in poor, half-starved condition. There are actually more deer and healthier deer in a region where natural enemies kill enough to keep them in balance with their food supply.

Adaptations for protection. Many animals and plants have adaptations to protect them from their natural enemies. Let us take coloring as an exam-

Fig. 13-2. The food relationships in the living world. What materials are going in cycles? What source of energy keeps the cycles going? What becomes of this energy?

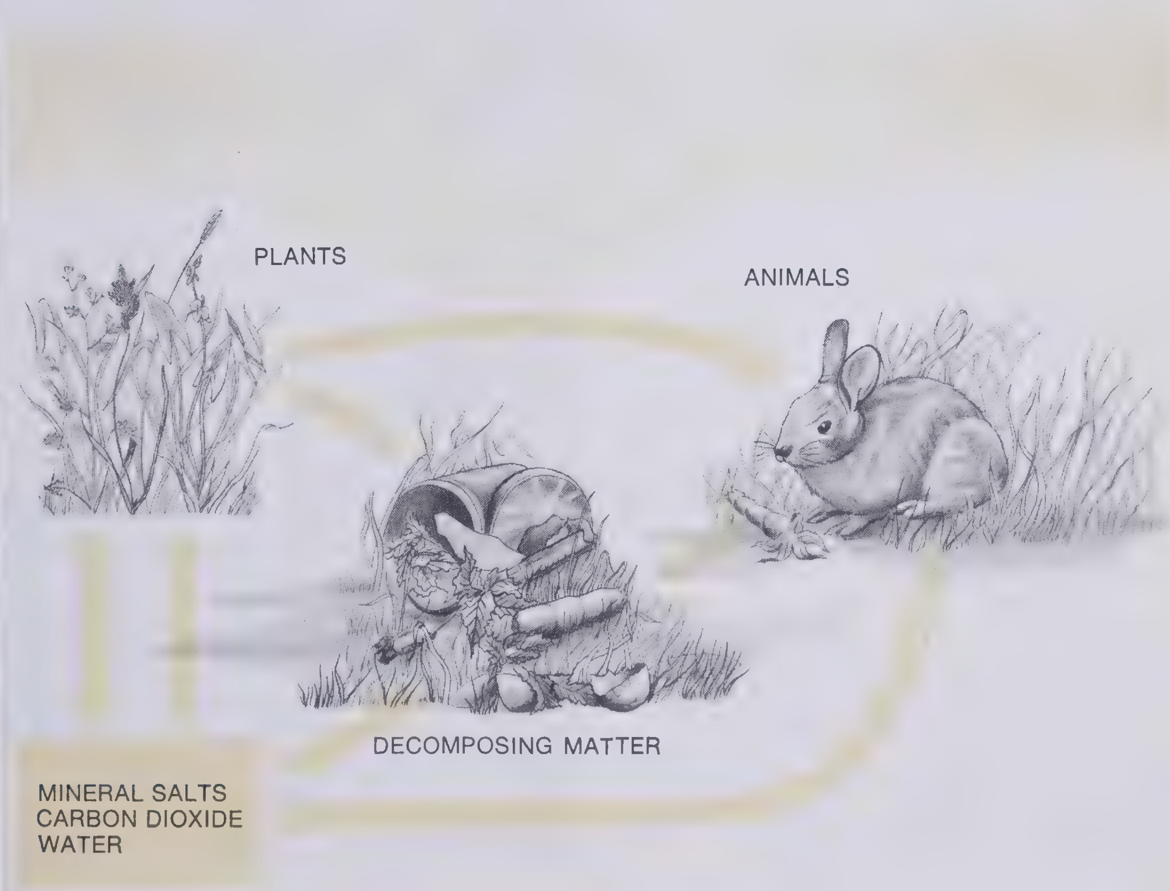


Fig. 13-3. How do wolves help the deer living in a region? Where there are no wolves what must take their place? (Dave Mech, copyright by The National Geographic Society)

ple. Animals that are hunted often have color patterns that make them difficult to see. You may walk within ten feet of a rabbit crouched on the ground without seeing it. Its brown and gray fur matches the color of the ground and dead leaves so well that you can look right at the rabbit without realizing it is there. The rabbit may not move until you are within a foot or two. Its running ability is, of course, another of its adaptations

Fig. 13-4. Can you find the mountain sheep in this photograph? Note how its color blends perfectly with the background. How does this fact help it to survive? (Eric Hosking)

for escaping from the flesh eaters. Most hunted animals have coloring that blends with their backgrounds. The giraffe blends in well with the light and shade under trees. Many moths rest all day out in the open on tree trunks. Their color pattern makes them look like part of the bark.

Animals that hunt also need color patterns that conceal them. After all, the hunter would go hungry if its prey could always see it coming. A lion matches the dead grass it hides in. A tiger blends with the sunlight and shade in the jungle. There are brightly colored spiders that wait on flowers for insects to come to them. The spiders match the flower petals so well that their victims do not see them in time.

Some animals not only match the color of their backgrounds, they also match the shapes of things around them. You may have seen a walking stick. This is an insect two to ten inches long which is shaped like a twig. It moves very slowly as it feeds on tree leaves. Hungry birds may fail to see the walking stick because of its twiglike appearance.

Fig. 13-5. A walking stick. Would it be easy for a bird to see this insect? (Dalton / Natural History Photographic Agency)

Competition. There is competition among living things. This does not mean that all living things are always fighting with one another. It means that they are after the same things such as food and space to live, and there may not be enough to go around. Trees, for instance, compete for space. Each tree must have room in the ground for its roots and room in the air to spread its leaves in the light. If another tree grows above it and shuts out the light, then the shorter tree may die. Competition is keenest among living things that are most alike. They are after the same things. The ones that are best adapted to their environment are the ones that survive.

Some animals have *territories*, which help to control competition. Some male birds, for instance, return north in the spring and each one selects his own piece of land for nest-building. The bird sits on a high perch and sings, thus letting other male birds of the same species know he has claimed this particular piece of territory. The others keep out unless they want a fight. By the time the females arrive and pair off with the males, the various territories are well established. This reminds us of a farmer who goes down to the courthouse to

Fig. 13-6. Cooperation between large and small animals is frequent in the tropics. Here, a flock of white birds perch on the backs of elephants to pick off ticks and other insects which may bother the large animals. The elephants, in turn, give the birds a secure spot so that enemies will not dare attack them. (H. W. Kitchen from National Audubon Society)

record the deed to his land. This is his way of telling other people, "This is my land. I will earn my living here. You keep out." He does not have to sit on a fence post and sing about it, like a bird, but the result is the same. Both bird and man have territories on which to obtain food to raise families.

Territories represent food supplies. Animals with territories are not so crowded that they cannot feed their young. Wolf packs hold large territories and will not allow other wolves to hunt there. Hyenas and lions also hunt in groups. They defend their hunting territories. Even a male cottontail rabbit defends its territory from other male rabbits.

Cooperation. Living things do not always compete. Sometimes the presence of one type helps another type. Bees and flowers are a good example. The bee obtains its food from the flower and the flower is pollinated by the bee. Both benefit. Earthworms in the soil loosen the ground, letting in air and water. Then plant roots can grow better. When roots and leaves die, they become food for the worms.

Wild cattle go in herds and cooperate in driving off any flesh eaters which may attack. Musk oxen, bison, (American "buffalo"), and African buffalo all show this kind of behavior. Flocks of crows often sit on high perches to watch for danger while the

others in the flock feed. Baboons cooperate in the same way.

We are not always sure of how each living thing affects the others around it. Some duck hunters once found that skunks were eating eggs from the duck nests in a certain marsh. These men thought it might improve the supply of ducks if they eliminated this competition. They did their best to wipe out the skunks with guns, traps, and poisonous baits. The result was fewer ducks! This was not what they had expected.

Careful study showed the reason for this surprising result. Skunks ate not only duck eggs. They also ate turtle eggs. With the skunks gone, snapping turtles multiplied rapidly. They ate young ducks and reduced their numbers far more than the skunks ever had. When skunks were allowed to increase in numbers again, the ducks also increased.

Fig. 13-7. Why do game laws often protect hawks and owls from hunters? (G. Ronald Austing from National Audubon Society)

Farmers often kill hawks and owls. They say that these animals kill chickens. Once in a while a chicken may be taken, but most hawks and owls eat mice. If the mice had no enemies, they would multiply to such numbers that they would ruin grain crops. The farmer would be put out of business. For this reason, game laws protect most types of hawks and owls in many states. Of course, the particular hawk that starts killing chickens will have to be destroyed.

Whole books have been written on the ways in which living things affect one another in the environment. We have mentioned only a few of these in this chapter. You can study living things and discover more of these relationships for yourself.

ACTIVITY

Food Groups. Find out what animals live in your part of the country. Your librarian can help you. You can write to your conservation department and ask for information. Perhaps where you live it is called the Fish and Game Department. Learn all you can about the habits of each kind of animal and decide which food group it belongs in. Make a chart to show this information.

Effects of competition. Plant several kinds of seeds fairly close together in a box of soil. Place the box in a window and keep it watered. Do not do anything else to it. Let all seeds grow, including

any weeds which come up by themselves. Watch what happens during the next several weeks. How many plants started to grow? How many kinds? How many of each kind are still alive and growing at the end of each week? Why do you think some of the plants die? Are some of them better adapted than others? What have you learned about the effects of competition among living things?

CHECK YOUR FACTS

1. **Make a list of all of the food groups. To the right of the list give the names of at least three living things that belong in each group. See if you can use examples that are not in the book.**
2. **Draw a cartoon showing a food chain of which you are a part.**
3. **Most states have deer but no wolves. What keeps these deer in balance with their food supply?**
4. **How does body coloring help animals survive?**
5. **How do our common song birds protect their territories? What advantage does this give them?**
6. **How do plants compete with one another?**
7. **How do hawks and owls benefit man?**
8. **Give a few examples of cooperation between living things.**

CHAPTER 14

Communities

As we have seen, the kinds and numbers of animals and plants in any place depends on many things. Besides the nonliving things, such as soil and climate, there are the effects of the different forms of life on one another. The plants and animals which live together in a local environment make up a ***community.*** Some communities are quite large. Others may be fairly small.

How communities are separated. Communities are separated from each other by some sort of barrier. Sometimes this barrier is easily seen. The shore, for instance, is a barrier separating a land community from a water community. Mountain ranges or deep canyons may separate communities. Often, however, the barriers are not so easily seen. An oak forest may grow right next to a maple forest. Differences in soil and soil moisture explain this. Oaks can grow in sandy soil that is fairly dry. Maples must have more moisture. A change from a ponderosa pine forest to one of spruce or fir is often due to climate, even though they grow in sight of one another. Ponderosa pines grow at a lower, warmer altitude. Spruce and fir may grow higher up on the same mountain.

The kinds of plants that grow in a community determine what animals can live there. Squirrels, porcupines, and bears can live in a forest. Antelope, prairie dogs, and bison can live on a grassy plain. There are several reasons for this. The animals must find enough of their kind of food. They must also be able to escape from their enemies. A squirrel escapes by climbing a tree. An antelope escapes by running away. The climate must also be right for the particular animal. Some animals can live in several different communities, but all the animals in two different communities are never the same.

Succession. Imagine an experiment that takes a thousand years to complete. Suppose we pick a large field of good soil somewhere. We plow and drag this field and leave the soil bare, with nothing growing on it. Then we watch for the next thousand years to see what happens on this land. Perhaps you think that this is too long to wait, but remember that this is an *imaginary* experiment.

The very next year, the ground will be covered with plants, mostly weeds. These weeds come up quickly from seed. Some of this seed was already in

the plowed soil and some was brought by wind. Here and there will be a few grass plants, but for the most part the plants will be weeds. In just a year or two we will see a change. The grasses do not have to start from seed each year. They live right through the winter and spread out more each year. After a few years the clumps of grass begin to grow together. Meanwhile the weeds begin to disappear. Eventually the entire field becomes a grassy meadow. The first weeds no longer have a chance. Their seedlings cannot grow on ground where the grass plants are tall enough to shade them out. Tree seedlings do not have much chance, either. They are also crowded out by the grasses. But certain plants which can grow with grass will be present. Wild carrot, wild aster, and goldenrod will find a place.

If we wait many more years we see another change take place. Here and there over the field a young tree or bush manages to grow. Once it becomes taller than the grass a young tree cannot be stopped. These young trees keep the sunlight away from the grasses underneath. New grasses that can live in the shade crowd out the earlier types. When enough trees have grown so that their tops touch, nearly all ground plants die out. The field now is covered by a forest.

But this is not the end. The first trees are a mixture of different kinds. Some of them can only grow to a height of ten or twenty feet. Others can grow much taller. These trees compete with one another. Some are sure to lose out and fail to survive.

Fig. 14-1. Succession ending in a climax forest community. Identify each of the various stages.

Finally the forest is dominated by just one or two kinds of trees, such as maple and beech, which are the ones best adapted to the combination of soil and climate in this area. There are a few other kinds of trees, and underneath are a few small plants. These are types that can get along with little light. This is called a ***climax community.*** It will go on unchanged as long as conditions remain the same.

When we have a series of different communities replacing one another in order, we call it a ***succession.*** In the succession we were just imagining, there was first a community dominated by weeds. Then came a grassland community, then a forest community, and finally the climax forest.

There would, of course, also be animals in these communities. In the earlier stages meadow mice, meadow larks, and grasshoppers might be among those present.

During the brush stage of the succession new animals would appear. These might include deer, foxes, robins, and chewinks. The final forest community would probably include raccoons, squirrels, deer mice, woodpeckers, and thrushes.

You may wonder why the climax community does not grow up at once. Why must there be a succession? In the case we have pictured, the climax community is a forest. The members of this community are adapted to forest conditions and cannot live in the open. The ferns and mosses on the forest floor would dry up and die in the open sunlight. Young maple and beech trees grow best in the shade. Each community in the succession changes the living conditions so that the members of the next community are able to move in. In our example the succession resulted in deeper shade. Shade-loving types finally win out and establish the climax community. The pioneer species did not survive.

If our imaginary experiment were carried out in some other region where conditions were different the succession would be different also and it would end in a different climax. In Kansas or Nebraska, for instance, the climax would be *grassland.* In parts of Arizona it would be *desert.* In northern Canada it would be a *tundra.* Do you see why?

You can look around your region and identify the various communities. Besides forests or prairies, these may include tamarack bogs, mangrove

Fig. 14-2. A bare area caused by a forest fire may be the beginning stage of a forest succession. (Standard Oil Co., N.J.)

swamps, pine woods, desert scrub, or mountain meadow, depending on where you are.

You can also watch for places in your region where plant succession is actually going on. These will be places such as vacant lots, fields, or places where fire has destroyed all of the former living things. The longer these spots have been left alone, the further along they will be in their succession. Can you predict what the climax may be in a particular area?

Balance in the community. In a climax community the numbers of each kind of living thing remain about the same from year to year. There is just so much room available for plants to grow in, so the number of plants is limited. The particular kinds of plants found there are those that are best adapted to that location.

Because food is available in a climax community, plant-eating animals may increase in numbers. This increased number of plant eaters provides food for the flesh-eating animals, so they in turn increase. But as the flesh eaters eat the plant-eating animals, the plant-eaters become scarce. With fewer plant eaters to hunt, some of the flesh eaters starve, and their numbers are in turn controlled.

The numbers of many animals may also be limited by their habit of defending territories. This spaces them so that not too many try to live in one area. Those too weak to hold on to a territory are driven out into environments to which they are not adapted. They either starve or are killed. Many animals have fewer young when living conditions are poor. This lower rate of reproduction brings them into balance with their food supply.

Disease may also limit the numbers of surviving plants and animals. When animals become too crowded, disease germs can be passed easily from one to another. Many animals die. Snowshoe rabbits, for instance, increase in numbers year by year until there are a great many of them in the woods. Then disease spreads rapidly and kills most of them. These rabbit populations build up to a peak every ten or eleven years. Over a period of years, however, the average remains about the same.

Thus in a climax community, the numbers of a given kind of living thing increase, only to be decreased again by natural enemies, lack of food, or disease. Because of these controls, we say that the living things in a climax community are in ***balance*** with

Fig. 14-3. Succession in a pond community may begin with water plants such as these algae. (Grant Heilman)

one another. You have already seen how deer are kept in balance with their food supply. You saw how skunks, turtles, and ducks were in balance with one another.

Mineral materials from the soil are built up into living protoplasm by green plants, and some of these materials are passed along to the animals which eat the plants. Death and decay return minerals to the soil, where they can be used again. Thus the buildup and the breakdown processes are also in balance with each other in the climax community. Energy from sunlight is absorbed by plants during photosynthesis. Plants and animals use this energy to carry on their life processes, so that energy use and energy intake are also balanced in the community. Of course, the greatest amount of food produced in a community is usually used by the green plants themselves. They need it for energy and for growth. The rest may be used mainly by animals. In this case the decomposers obtain only what food value is left in dead plants, dead animals, and animal wastes. They may not even have a chance to decompose the dead animals. The scavengers get them first. A grassland community is like this. In a forest the situation is different. Few animals are able to use tree leaves or wood as food. Decomposers are more important than animals in the food chains of forests. They cause decay of dead leaves and fallen tree trunks.

Upsetting the balance. As we have said, the climax community will be permanent as long as conditions remain the same. Sometimes conditions change. For instance, fire may destroy a forest community. Then a new succession will begin. This succession might include communities of weeds, of grass, of brush, and of small trees. Finally the original type of forest community would become established once more. It would return because it is the community best adapted to that particular soil and climate.

A permanent change in conditions will upset the balance so that the old climax community can never return. Then a succession starts leading to some new climax. A change in climate can do this. Twelve thousand years ago there were communities of grassland and forest in parts of Arizona and New Mexico which today are desert. Ice and arctic tundra once covered much of the land in the northern areas, where today there is rich farmland. These changes in the living communities resulted from extreme changes in climate.

New kinds of plants or animals can enter a community and change it permanently. An example of this may be seen in some hemlock communities of the North. Hemlock trees formed

Fig. 14-4. This shows a later stage in pond succession. (Lynwood M. Chace)

heavy, dark stands of forests on the better soils. They were the most important trees in these climax communities. Then sugar maple trees entered the region. They are now slowly crowding out the hemlocks. In time the hemlocks probably will be entirely replaced by maple.

Man in the community. When the first settlers came to North America they found the whole eastern half of the continent covered with forests. They cut down most of these forests and made farms. Thus a new kind of living thing entered the community and changed it. Man established a new community dominated by himself, his farm animals, and his crop plants.

In many parts of the world man has farmed the land only to start successions which have led to semidesert conditions. Careless farming methods destroyed the soil. The community that resulted is an open growth of grass and weeds, with much bare ground. Today a few people wander across this poor land, seeking food for their sheep and goats. This is the new climax community. Soil conservation is a very important topic. We shall discuss it in Chapter 15.

ACTIVITY

Sealed communities. In nature the producers, the animals, and the decomposers are usually in balance. Materials are used over and over again, but new energy must keep coming into communities from the outside. In what form is this energy? How small could a community be and still be fairly well in balance? Set up the following miniature communities and see how long they can keep going.

1. Place a small snail and a piece of water plant in a test tube three quarters full of aquarium water. Seal the tube with a cork or rubber stopper. Set this simple "community" where it receives plenty of light but not direct sunlight.
2. Prepare another tube in the same way but without any plant life.
3. Prepare another test tube like the first one, but include only plant life.
4. Prepare a test tube exactly like the first one, but keep it in a dark closet.
5. Make a small aquarium in a quart mason jar. Put a little soil on the bottom. Cover this with sand. Fill three quarters full with aquarium water. Plant several water weeds. Add three or four snails. Seal shut with a lid screwed tightly down against a jar ring. Place the jar in a light (not sunny) location.
6. Make a similar sealed aquarium using a gallon jar.

Keep careful records of what happens in all of these sealed communities. When do the plants die? When do the animals (snails) die? Do plants or animals grow? How much? For how long? Do the snails reproduce? When does everything in the community die? What evidence do you see that decomposers are present in the community? Try to explain the different results that you observe.

CHECK YOUR FACTS

1. What do we mean by a community in nature?
2. Give some examples of communities which are found in your region.
3. What are some of the conditions that cause certain communities to develop in certain places?
4. What is succession? Give an example.
5. What is a climax community? Give an example.
6. What do we mean when we say that a climax community is in balance?
7. What things may upset the balance in a community?
8. What are two things that may result when the balance in a community is upset?
9. How does man affect the communities he lives in? Are the results always what he expected?

CHAPTER 15

Conservation of Soil and Water

There is a limit to the numbers of living things that can exist in any community. This is just as true of man as it is of deer or wolves. There is a limit to the amount of food we can expect to produce. Clean water may become scarce; in fact it is already scarce in some places. The open spaces that make life so enjoyable can easily get too crowded. The more careless we are in managing our natural resources, the sooner we will reach the time when our communities can no longer support us.

It is important, therefore, that we manage our resources wisely. This is what we mean by the word ***conservation.*** If we practice good conservation we can always have enough soil, enough water, enough forests, and enough wildlife for our comforts and needs. These resources can keep renewing themselves if we let them. But we have to maintain balanced communities. In this chapter we shall deal with one part of the problem. It is concerned with soil and water.

Food and many other materials useful to man come from plants. These plants must get water and minerals from the soil. Often the effect of farming on soil is to ruin it. There are many places in the world where bad use of soil has turned what was once good land into desert. A scattering of underfed people live in poverty, where large populations once lived in plenty. In bygone days farmers often raised crops until the soil was exhausted. Then they moved on to other areas, leaving ruined land behind them.

This sort of thing can happen here if we are not careful. Much of the original rich soil has already been damaged or washed away. The population is growing while the soils are becoming poorer and poorer. In time this could bring hunger instead of our present food surpluses.

Even if you live in the city good soil use is still one of your problems. The food used by city dwellers comes from farms. If there were a food shortage farmers would still have food. But supplies in city markets would get smaller and food would cost much more. City people should understand this situation and be ready to support good conservation programs.

If you live on a farm you should become an expert at the job of conserving the land you work. Making a living for the family is not enough. The farmer has a responsibility to hand his land on to the next generation in at least as good a condition as he found it. If he does not do this he has robbed future citizens of their right to live. People cannot live without food and food comes from the soil.

Soil structure. Soil is made up mostly of small bits of rock. These tiny rock particles vary a great deal in size. In some clay soils many of them are too small to be seen even under high power microscope. These tiny clay particles stick close together. This is what makes clay so gummy when it is wet, and so hard when it is dry. Sand grains are large enough to be seen without a lens. Pieces of gravel are even larger. Many of them are actually small stones. Other soil particles can be anywhere in between the sizes of clay and gravel particles. A ***loam*** soil is one that has a variety of rock particles in it.

Soil begins to form when solid rocks break down. Any rock exposed to the weather will break down in time. Heating in the hot sun and cooling at night will crack the rock. Water, freezing in the cracks, will break it down still more. Rainwater is slightly acid. It will attack the rock chemically. Oxygen from the air and carbon dioxide from the plant roots also affect it. In time the surface of the solid rock crumbles completely. It becomes soil. This breakdown process is called ***weathering.***

Glaciers also break up rocks. A glacier is a large ice layer that moves slowly across the land. It may be thousands of feet thick. During the last Ice Age glaciers moved across Canada and south into the northern states. The moving ice scraped against the rocks it passed over, grinding them into soil. Some of these glacial soils around the Great Lakes are as much as four hundred feet thick.

The chemical changes that take place in the rock particles release dissolved mineral salts into soil water. Naturally some types of rock materials contain more of these minerals than others. Sandy soils are usually poor in mineral salts.

Clays are rich in minerals, but clay soils are very dense. It is hard for roots to grow through them or to obtain enough air because of the small spaces between each particle. In general, a farmer likes a loam soil best. It is easier to cultivate than the dense, gummy clay soils. Loam is richer in minerals than the sandy soils.

Plants grow on the surface of the soil, and their roots grow down into

Fig. 15-1. This is a cut downward through the soil. Why is the top layer so much darker than the deeper layers? (USDA—Soil Conservation Service)

it. When plants die, their leaves, stems, and roots are mixed into the soil and decay. The decaying bits of plant material are called ***humus***. Humus is dark in color, so the upper layer of soil is darker than the soil underneath. This upper layer is called ***topsoil***. ***Subsoil*** is the lighter colored soil underneath. Humus, of course, contains minerals which were once part of the plants it came from. These minerals are released during decay. They can be taken in by plant roots and used over again.

Humus improves the soil in some ways. Its spongy fibers hold moisture in the topsoil where the roots can reach it most easily. It also has the ability to hold the dissolved minerals that keep coming from the rock particles. These minerals are soluble. They would normally sink deeply into the ground along with the rainwater. Humus tends to keep the minerals in the topsoil where roots can absorb them.

Plant roots are not the only living things in the surface of the soil. Here you find a great many bacteria, fungi, algae, and protozoa. Among the bacteria and fungi are types that cause decay of humus. In the surface soil there are also various worms and insects. There may even be larger animals such as moles, mice, and gophers.

Topsoil, then, is a very complicated mixture. It contains rock particles, air, dissolved minerals, humus, and many forms of living things, both plant and animal. You will begin to see that a good rich topsoil takes a long time to form. It is estimated that nature may take as long as 400 years to form one inch of topsoil. It is the richest part of the soil and is what we are most concerned with in soil conservation.

Of course water must be present in the soil. Nothing will grow without

Fig. 15-2. Ground water. Where does it come from? Notice that a lake is a place where the water table stands above the surface of the ground.

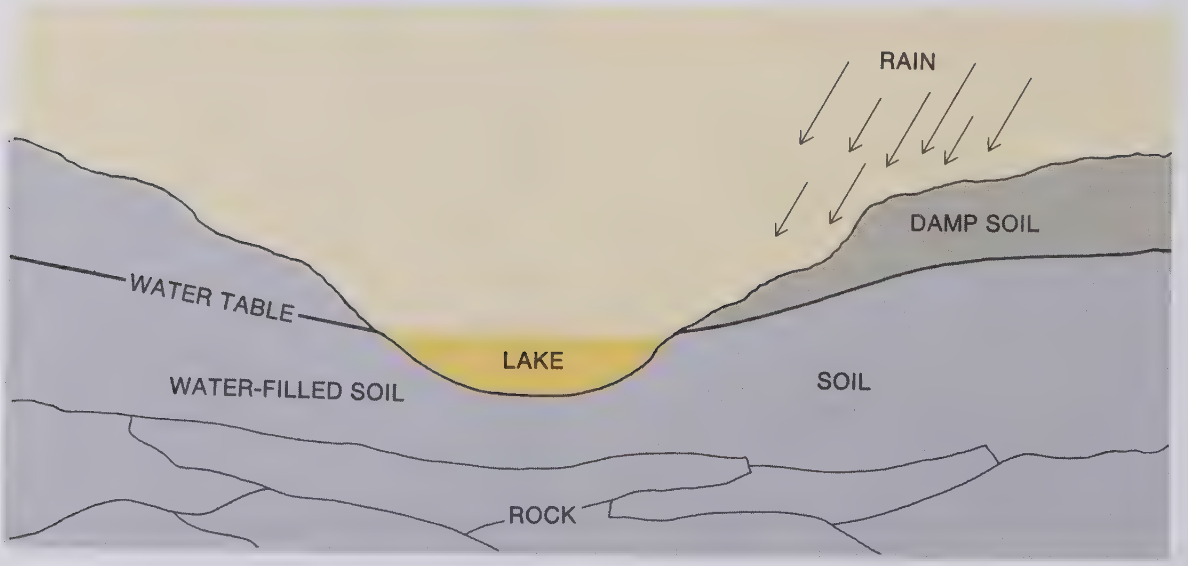


Fig. 15-3. A farmer using fertilizer to add nutrients to the soil and thus assure better crop production. (USDA—Soil Conservation Service)

it. ***Groundwater*** is rainwater that has soaked into the soil.

There are little spaces between soil particles. When rain falls on the land, some of the rainwater soaks into the ground and sinks downward through these spaces. When water reaches the solid rock layers beneath the soil, it can go no farther. The spaces in the lower levels of the soil become filled with water. The top level of this water-soaked part of the soil is called the ***water table.*** Above the water table the soil is moist, but not really waterfilled. Here, the spaces between soil particles contain some air. The water forms a film around each soil particle. Roots get their water from this damp soil.

Loss of minerals from the soil. Good topsoil supplies plants with all the minerals they need. But even with good soil, the farmer has a problem. He grows crops year after year and sends them to market. Minerals which came from the land go off to town as part of meat, grain, vegetables, and other farm produce. These minerals do not return to the soil as they would in a natural, balanced community. New minerals may not form rapidly enough to make up for the loss. Such loss of fertility is called ***soil depletion*** (dee-*plee*-shun). Depleted soils produce less and less as time goes on.

The old method of dealing with soil depletion was to let the land sit unused for a period of time. The action of weathering and of the grass roots upon the rock particles would build up a new supply of minerals. The soil's fertility would be increased. This

method is not used much today because it takes too long. Most farmers use fertilizers to prevent soil depletion. About one third of all the food produced in the United States could not be grown if fertilizers were not used. Our better soils would soon be worn out.

A fertilizer is any material which adds useful minerals to the soil. Animal manures make excellent fertilizers. They contain minerals the plants can use, and they also add humus to the soil. But there is never enough manure to do the whole job. Commercial fertilizers must also be used. These are made from chemicals in fertilizer factories. There are different kinds to meet the needs of different soils.

The three elements most likely to be lacking in farm soils are nitrogen, potassium, and phosphorus. If a fertilizer has all three, it is called a complete fertilizer. For some soils other elements must be added. In certain southern areas cobalt is lacking. Plants do not need cobalt but animals do. Fertilizing with very small amounts of cobalt makes it possible to produce beef on these soils. The cattle obtain their cobalt from plants grown on the fertilized soil. Some soils need other special fertilizers.

Soil depletion can also be slowed down by ***crop rotation.*** This is the practice of not planting the same crop on the same ground every year. A common rotation in the dairy regions is to plant corn for one or two years. The corn is followed by oats, which in turn is followed by hay. The hay (usually an alfalfa and grass mixture) is left in for about three years. Then corn is planted again, and the rotation repeats itself. Other crops are used in other places, but the idea is the same. Each crop takes a little different combination of minerals from the soil, so no one mineral is used up too rapidly. Alfalfa adds nitrogen in the form of nitrates to the soil. The hay crop also improves the soil by increasing its humus content. On some corn belt farms rotation is not used. Heavy use of fertilizers makes it possible to plant corn year after year and still have high yields.

The wearing away of soil. ***Erosion*** (ee-*roh*-zhun) is a more serious form of damage. Depleted soils can be improved by proper handling, but erosion carries away the soil itself. The fertile topsoil is lost.

Water erosion takes place in a number of ways. Raindrops striking bare ground splash the soil particles loose. As the water runs downhill, these loose particles are carried with it. Each storm carries more topsoil downhill. This process may go on so gradually that we do not notice it. The whole surface of the hillside loses its topsoil, and remember that topsoil is the fertile part of the land. When the whole surface wears down evenly in this way the process is called ***sheet erosion.***

Gully erosion is easier to see. The water running downhill forms channels in the soil. These channels are cut deeper and deeper until gullies are formed. A gully even a few feet deep prevents the farmer from using that part of his field. He cannot run his tractor across it. In time the gullies may cut the hillside so badly that it must be abandoned. It is no longer farmland.

Fig. 15-4. Erosion has cut a gully through this vineyard. Where has the missing soil gone? Can the soil that is left ever be used for growing crops again? (USDA—Soil Conservation Service)

Bad farming methods greatly increase the rate of water erosion. Some crops should not be planted on steep slopes. These are row crops such as corn, cotton, tobacco, potatoes, and beans. The bare ground between the rows is loose and very easily eroded. The damage is worse when the rows run up and down the slope. Each furrow left by the cultivator becomes a channel leading water downhill rapidly. Gullies often begin to form in this way.

Soil erodes much more slowly when it is covered with plant life. The leaves break the force of raindrops striking the ground. Dead leaves and humus protect the surface from the main force of the running water. They hold back the water, giving it more time to soak into the ground instead of running downhill. This not only prevents erosion, but also puts more water into the ground, where it can be used by plants.

Ways to prevent water erosion. The best protection for soil is a forest cover. The next best is a dense sod of grass and other pasture plants. Small grains, such as wheat, oats, and rye are fairly good. Good conservation practice calls for keeping the steepest slopes in forest. Trees are useful because their roots hold the soil and fallen leaves hold the water. This land would soon wash away anyway if it were farmed.

Slopes that are a little less steep can be used as permanent pasture. The grasses provide food for cattle without exposing the soil. Of course the pasture needs fertilizing to keep it productive, and it must not be overgrazed. If the animals eat off the grasses too close to the ground, the soil is

exposed to erosion, both by wind and by water.

Hay can be planted on fairly steep slopes. The sod in a hayfield gives good protection to the soil, though not quite as good as that of a permanent pasture. The land also may suffer damage at planting time before the hay has grown enough to cover the ground.

The more gentle slopes can be planted with small grains. These give fair protection while they are growing, though there is danger of erosion at plowing and planting time, when the soil lies bare. These small grains are such crops as wheat, oats, rye, and barley.

Row crops should be grown only on fairly level ground. This means that in rolling country such crops as corn should be planted in the valleys and on the level hilltops. Other crops and trees should occupy the slopes.

For many years conservation experts have recommended ***contour plowing.*** This means plowing sideways, across the hillside, instead of up and down the slope. Each furrow becomes a little dam which slows the flow of the water. Slow-moving water does not do a great amount of damage. Also, slowing the rate of flow gives the water more time to soak into the ground. If the plow is always set to throw the furrow uphill, the downward movement of soil due to erosion is checked.

Contour plowing is not quite as simple as it may sound. Ordinary plows cannot be used. Special kinds which can throw the dirt either way are needed. Hillsides do not have the same angle of slope in all places. This means that the strips of plowed land must be wider at some points than at others,

Fig. 15-5. Strip cropping and contour plowing. How do these practices help to prevent soil erosion? (George Leawens / Photo Researchers, Inc.)

and that furrows will run into one another. Plowing in this way is much harder than going in straight lines. Plowing up and down the slope is easier than plowing across it. As a result, the old harmful ways of plowing are still used more often than the contour method.

The money situation in the country affects plowing practices. In hard times a farmer feels that he cannot afford the thousands of dollars needed to buy equipment and to relocate fence lines. In good times he is tempted to make as much money as possible while he can; so he plants the slopes with row crops and plows the easy way. When the land has become badly damaged, he finally sees the need for soil conservation. Now, however, it is too late! His land does not produce well enough to pay the cost of improving it.

Strip cropping is a conservation method that can be used along with contour plowing. Instead of laying out the land in square fields, each crop is planted in long, narrow strips which run across the slope. Water running downhill across these strips is slowed down. A strip of hay, for instance, soaks up much of the water flowing across it. This protects a strip of some row crop that grows next to the hay. On the other side of the row crop another strip of hay also slows down the water flow.

Terracing can also be used. A permanent, low, broad ridge is formed by grading machinery at the lower edge of each strip of crop land. Farm tools can be operated right over the tops of these terraces, so they are not in the way. Water collects behind them and is led around the slope to specially constructed outlets. These outlets may have stone or cement at the ends of the terraces to prevent gullying. The water flows downhill through grassy runoff channels.

Whenever topsoil has been lost by erosion it is desirable to rebuild it from the exposed subsoil. The original topsoil took thousands of years to form, but some new topsoil can often be produced in as little as eight or ten years. This is done by planting rye, clover, alfalfa, or other plants on the exposed subsoil. Heavy use of lime and fertilizers enables these plants to grow. They are not harvested, but are plowed right back into the ground, and the process is repeated. Then grass is allowed to grow for several years. As a result, humus is added to the soil. Decay bacteria working on this humus produce acids which attack the rock particles, releasing dissolved minerals. Grass roots loosen the soil and put it in condition for farming. Of course this method will not work if the land is all cut up by gullies, and few farmers can afford to wait ten years to start earning an income from their land again. It is very important to keep the topsoil in good condition in the first place.

Floods can erode land. ***Floods*** often produce severe water erosion. Swift currents from flooding streams can either wash away topsoil or bury it under layers of gravel. Only the more violent floods do this. In general, floods improve the soil in the flat lands which cover the floors of the river valleys. Flood waters carry fine particles of topsoil which have eroded from the higher slopes of the valley. This material settles on the surface

Fig. 15-6. Flooded land. How do floods affect the soil? How can they be prevented? (United Press International Photo)

of the valley floor, deepening its layer of topsoil. Much of the best land in the world is found on these flood plains of river valleys. Anyone farming such land must expect floods and must place his buildings on high ground.

Floods become violent and destructive when too much water runs off the land instead of soaking in. Good soil conservation on the upland farms reduces flooding in the lowlands. Forests on the ***watersheds*** also help. Watersheds are the higher slopes and ridges at the upper ends of river valleys. These lands have steep slopes and should not be plowed. If the trees on them are destroyed, the soil erodes away. Water does not soak into the ground as it should, but runs rapidly downhill, causing floods.

When forests cover watersheds, rainwater is kept from running downhill. It soaks into the dead leaf layer and on into the ground without causing erosion. This ground water comes out later in springs which keep the streams flowing all summer.

Water which soaks into the ground is available for plants. Allowing water to run off the surface has the same effect as if the area had little rainfall. Less food can grow on the land because of poor water supply. Wells often go dry in regions where soil conservation is not practiced. Water runs off in streams instead of being added to the groundwater supply.

You will notice that in talking about soil conservation we have ended by talking about water conservation. The two are closely related. In the West, the conservation of water is important because of irrigation. Water from melting snow and from rainfall in the mountains is stored behind dams. This water can then be used all summer long to irrigate dry lands in the valleys and plains at the base of the mountains. River and well water are also used. In all of

these projects the use of water must be gauged so that the water supply lasts through the summer. If the supply runs out before the crops are mature, there is trouble.

The wind causes erosion. ***Wind erosion*** takes place wherever soil becomes very dry. The topsoil blows away as dust. Wind erosion is a problem all through the West. Much of this land was originally plains covered with short grass. The grass protected the dry soil from blowing away. Bison, elk, and antelope ate the grass. If it dried up, they moved on.

Two things happened to change this picture. Cattle and sheep were brought in to replace the bison. Often the land was overgrazed. Too many animals were fed on limited amounts of land. They could not move on to better pasture as the wild animals did, because they were fenced in. The grass was eaten off so close to the ground that it died out. Wind got at the bare soil, and dust storms became common. The eroded soil could not grow as good grass as before. Weeds increased in number. Much of this land looks like a desert today. The obvious cure for this situation is to limit the animals to numbers the range can feed. Programs to restore a grass cover are also needed.

In other parts of the dry West the land was planted with wheat and other crops. In some years there was enough rain to keep the crops growing. But the dry years came. Then there was little rain and the crops failed. Wind blew the dry topsoil off the bare, plowed fields. The result was known as the American "dust bowl."

Fig. 15-7. Wind erosion in a cotton field. How do you think such a field can be made productive again? (USDA—Soil Conservation Service)

In farming where the land is dry, plowing should be done crosswise to the direction of the most common winds. Furrows hold the dust better if the wind blows across them. Strip cropping helps. Strips of standing crops slow down the wind so it does not hit the plowed strips as hard. Sometimes strips of trees are planted to protect fields from the wind. Trees cannot grow from seed in such dry country, but often they will live if young trees are planted and watered until they are well started.

Often wind erosion problems must be attacked on a large scale. One farmer may practice good conservation only to have his land buried in deep drifts of dust that blows in from other farms. Farmers over wide areas must cooperate in order to bring such situations under control.

Soil and water conservation programs. Our government helps in setting up local soil conservation programs all over the country. Agricultural engineers study the best methods for use in each particular area. They give advice to the farmers in the region and operate demonstration farms.

Actually a great deal still needs to be learned about soil conservation. Better methods need to be developed. Better plows, cultivators, and other equipment would serve to make the job easier and more effective. Many farmers still need to become conscious of the great importance of soil conservation to themselves and to the future of their country. City people need to understand the importance of the problem and to cheerfully pay their share of the cost of a good conservation program.

Fig. 15-8. Note the rows of trees planted up and down and across these fields. Such trees are called "wind breaks" and help to prevent wind erosion of the soil. (Grant Heilman)

ACTIVITY

Effect of plant cover on soil. With a spade dig a square cornered block of sod from the ground just the right size and thickness to fill a greenhouse flat level with the top (a shallow wooden box will do if you do not have any flats). Fill another flat with soil. Place each flat on a slant as if it were part of a hillside. The lower edge of each flat should rest in a shallow pan. Pour a pitcher of water down the slope of one flat and then repeat with the other. Which surface allowed more soil to wash into the pan? How many pitchers of water must flow down each flat before a small gully is formed in the surface? What does this experiment show about the way in which steep hillsides can be protected from soil erosion?

CHECK YOUR FACTS

1. What is conservation?
2. Why is soil conservation very important to all of us?
3. How is soil formed?
4. What are four kinds of soil? How could you tell them apart?
5. Name several ways in which topsoil is different from subsoil.
6. What is the water table? From what part of the soil do roots get their water?
7. What causes soil depletion? What are two ways of overcoming the problem of depletion?
8. What is the difference between sheet erosion and gully erosion? Which do you think is worse? Why?
9. How does the growing of row crops damage soil? What kind of land is best for growing row crops?
10. How does a growth of plants help protect soil? How might plants be used to stop a gully from growing deeper?
11. Place these forms of plant growth in order. Start with the type which gives soil the best protection and end with the one that gives the least protection: corn, wheat, forest, a permanent grassy field, a hay field.
12. Explain how each of the following helps to reduce soil erosion: contour plowing, strip cropping, terracing.
13. How can new topsoil be rebuilt from subsoil?
14. How may floods improve the soil? How may they harm it?
15. How can forests on watersheds serve to reduce river flooding?
16. How did overgrazing damage the plains?
17. How can plowing the grasslands do harm to soil?
18. Explain three or more ways in which land may be protected from wind erosion.

CHAPTER 16

Conservation of Forests

Nearly half of the United States and Canada once were forest lands. A large part of this forest land has been cleared for farming, but there are still many farm woodlots. There are also many areas that are much too rough, or that have soil that is too poor for farming purposes. Such areas are still in forests. These remaining forest areas must supply us with our lumber now and in the future.

The forest regions. In the United States and Canada there are six main forest regions. They are located in the following places:

1. *Northern spruce and fir forest.* This forest of evergreens covers a large area. It reaches from central Alaska across Canada to the Atlantic Ocean. It lies far north, just south of the Arctic tundra. This is mostly cold, wild country where there are few roads or people. You might think such a large forest area would furnish a great deal of valuable lumber, but it does not. The trees are not very big and growth is slow because of the low temperature.

2. *Central hardwood forest.* Once this was a very large forest region. It reached from the East Coast to the prairies of the Midwest. Some of this forest grew on very good soil. So in many places it was cleared away to make room for farmlands. Some forest, however, remains on the slopes of the eastern mountains. Some also remains in woodlots. A *woodlot* is simply a part of a farm which is left covered with trees. The woodlots on farms are not ordinarily thought of as forest land, but actually they add up to a large total acreage. Much of the hardwood lumber for furniture comes from farm woodlots. If the average farmer managed his woods as a forest, a great deal more lumber could be produced.

All too often farm woodlots are treated as just extra pasture land. Cows kill the young trees so that there is no replacement as the older trees die. The large trees do not grow as well as they should because their roots are injured by the trampling and packing of soil by the cows' hoofs. Grass does not grow well under the trees, so the result is poor pasture and poor forest. These lands should either be cleared and made into good farmland, or they should be managed as true forest lands.

Maple, beech, gum, ash, oak, and hickory are a few of the many trees growing in the eastern hardwood region. Lumber from these trees is used mainly for making floors, furniture, woodwork, and tool handles.

3. *Southern forest.* The coastal re-

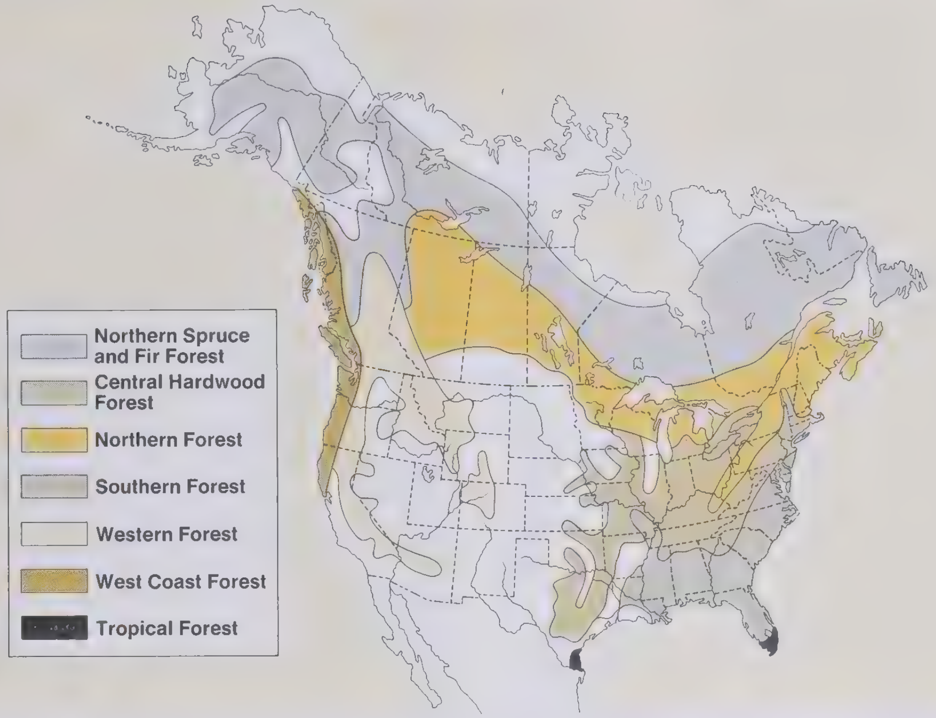


Fig. 16-1. This map shows the original forests of this country and Canada. Are all these areas still in forests today?

gion of the South, from the Carolinas to Texas includes a great deal of sandy soil. This was once covered by forests. Some of this land is now used for farming, but a great deal is still in forest. Longleaf pine, loblolly pine, and slash pine are some of the trees that grow here. Much of the "yellow pine" lumber sold today comes from the South. These southern pines grow rapidly, sometimes reaching saw-log size in only 50 years. Southern forests produce over a third of the nation's lumber and nearly all of the turpentine. Turpentine is distilled from the sticky juice that comes from pine trees. In some areas the Southern forest also contains oaks, pecans, and other hardwood trees.

4. *Northern forest*. This is really an in-between region where the change takes place between the Central hardwood and the Northern spruce-fir forests. It includes much of northern Minnesota, Wisconsin, Michigan, New York, and Maine, along with parts of southern Canada. A great deal of pine grows in the Northern forests along with stands of spruce, fir, and hardwoods. The Northern forest region once led the nation in lumber production. White pine was the most valuable tree. Lumbering operations, followed by fires, destroyed the original forests. The new growth is often of poor quality, so that this region does not produce nearly as much lumber as it could. Much of its present production is in small logs used for paper pulp. But in time the Northern

A C B D

Fig. 16-2. These pictures show some typical forests of our country. *A.* central hardwood forest; *B.* yellow pine forest of the southern states; *C.* Pacific states forest; *D.* redwood forest of California. (all from U.S. Forest Service)

forest could again be a leading lumber-producing region.

5. *Western mountain forests* grow on the slopes of the Rockies, Sierras, and other interior ranges of the West. The valleys and plains between these mountains are dry grasslands or deserts. But rain falls on the high slopes, providing the water necessary to grow trees. These are evergreen forests, producing important amounts of lumber for general construction.

6. *West Coast forest*. This forest grows on the coastal and Cascade mountain slopes from the middle of California all the way to Alaska. The rainfall is very heavy, producing a true rain forest. It includes beautiful stands of redwood, pine, Douglas fir, spruce, and other important evergreens. Away from the coast this forest blends into the drier Western mountain forests. This coastal forest region supplies more lumber than any of the others at the present time.

Forest uses. Lumber is the most valuable product of the forests, but they supply other important things also. Most paper is made from wood fiber. This paper pulp, as it is called, must come from the forests. Small trees only eight or ten inches thick will do, so species like jack pine and aspen can be used. It takes all the trees on 40 acres of land to produce the paper for just one Sunday edition of a large city newspaper.

Turpentine, pine tar, and resin all come from southern pines. Tanning

Fig. 16-3. A paper mill. Notice that small logs which might not have much use otherwise, can be used for the making of paper. (U.S. Forest Service)

materials like hemlock bark and chestnut oak bark once served to tan leather. Wood fiber from trees is now used to make wallboard, plastics, alcohol, camera films, and soil conditioners. From the wood we also get dyes, oils, stains, sugars, and chemicals used in paints, soaps, and floor coverings. Even the sawdust that is formed when trees are sawed into boards has value.

The forests are also important as homes for wildlife. They are recreation areas for hunters and campers. Forests on watersheds prevent erosion and reduce the flooding of rivers.

Forest fires. The most serious threat to a growing forest is fire. Fire not only kills the large trees, it kills the seeds in the ground and destroys much of the humus. Such a fire leaves bare soil lying open to the possibility of being ruined by erosion.

When the trees were cut in the Northern forest region, fires were allowed to burn through the dead pine branches which were left on the ground. If these fires had been prevented, the young trees already present would have grown up to replace the old ones. Crooked or old trees not fit for lumber were often burned. These trees could have produced seeds for a new growth of young trees. By this time the Northern forest would again be producing large amounts of lumber. As it is, trees such as aspen and birch stand where white pine should be growing. It will still be a long time before the slow succession of plant communities finally restores the climax forest.

In most of the main forest regions of this country there is now good fire protection. Lookouts are stationed in fire towers all through these areas. If a fire is sighted from a tower, the forest ranger in charge of that district directs a crew of fire fighters to put it out. Men in airplanes fly over the forests to look for any signs of fire. Forest fires still do damage, but they do not spread unchecked over hundreds of square miles at a time the way they once did.

Fig. 16-4. A raging forest fire and a piece of land that has been severely burned over. How long will it be before the land will produce any lumber again? (U.S. Forest Service; Weyerhauser Company)

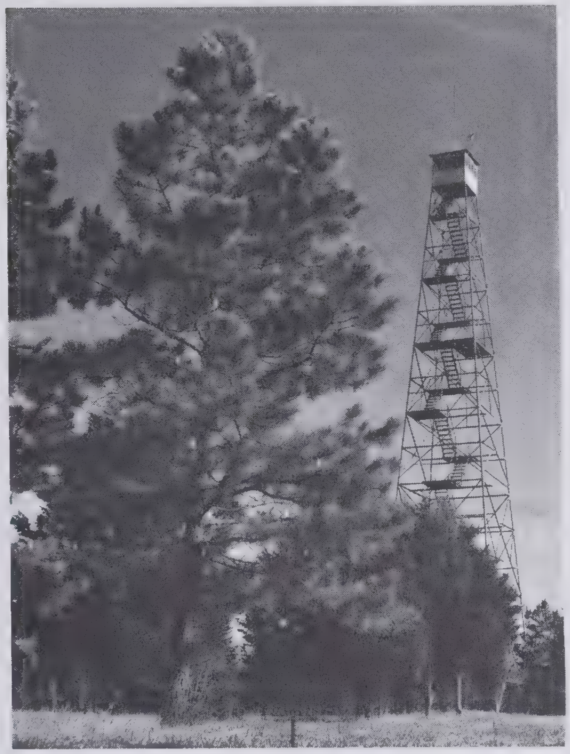


Fig. 16-5. A forest look-out tower. Men in these towers watch for smoke so that fires can be stopped before they can spread very far. Much of this work is now done by airplane patrols, too. (American Forest Products Industries Photo)

Lightning can start forest fires but most of them result from human carelessness. People fail to prevent the spread of the fire when they are burning brush, or they fail to put out campfires, or they throw away lighted matches and cigarettes. Some fires are started deliberately by "firebugs."

If you ever camp in forest areas, be sure you are careful with fire. Be sure your campfires are not built on rotting logs. A rotting log can smoulder for days and finally break out into open flames which start a forest fire. Scrape the humus layer off the ground and build your fire on bare soil. Before you build any fire be sure to check with the local rangers or fire wardens. In dry weather it is sometimes against the law to build any fires outside the stoves found in the forest camp grounds. If you see a forest fire, go *at once* to the nearest telephone or ranger station and report it.

Forest management. Fire protection is the most important part of forest management, but there are several other things that can be done. Where small trees grow too close together, none can grow well. Some of these trees may be cut out to give the rest of the forest a better chance. This is called ***thinning.*** Sometimes crooked trees, diseased trees, and trees of

Fig. 16-6. In a forest like this only the large trees are to be cut. This practice of selective cutting allows the smaller trees to grow to full size and eventually become useful for lumber. (Tall Timbers Research Station)

less desirable species are removed, leaving only the more valuable trees to grow and produce lumber. This is ***improvement cutting.*** Obviously thinning and improvement cutting can be combined in a single operation.

Reforestation is an expensive process, but it is sometimes used to speed up the return of forests where there are no seed trees to do the job naturally. Young trees are started in nurseries and then set out to grow in the forest areas. This used to be a hand job, but now there are tractor-drawn machines which can plant the seedlings much more rapidly.

When the time comes to cut trees for lumber, there are two good ways to do it. One of these is ***selective cutting.*** Only the mature trees are cut. Other trees are left to grow larger. With this method there is always a forest. Not many trees are cut in any one place, but some cutting goes on all of the time. A forest managed in this way yields a steady supply of lumber. It also gives steady work to the loggers.

When all of the trees in a forest are about the same age ***block cutting*** may be used. One whole area, or block, is cut off completely. Trees surrounding the block shed seeds into it. The block must be small enough so that the seeds can reach all parts of it.

Each block of land reforests itself if fire is kept out. By the time the last block is cut, the first one has regrown. This method also gives a steady supply of lumber and of jobs.

Fig. 16-7. Block cutting. Notice how all trees have been cut in blocks or patches. Seeds blow in from the surrounding areas and start new trees in these cut blocks. Is block cutting a good method to use in all forests? (American Forest Products Industries Photo)

Block cutting will only work well if the young trees grow in the open sunlight. Young Douglas fir trees will do this, so block cutting is often used in the extensive Douglas fir forests on the West Coast. It is also used in the pulpwood stands of jackpine and aspen of the Northern forest. Young white pine trees do not grow well in the open because sunlight favors the growth of insect enemies. White pines develop later in the succession and must always grow in the protective shade of other trees. Therefore, lumbermen should use selective cutting on white pine lands.

Fire used on purpose. Strange as it may seem, fire is sometimes used as a form of forest and grassland management. For the first several years of their lives longleaf pines grow only a few inches tall. Their long needles stick out in all directions like a ball-shaped brush. If too much dead leaf material piles up on the ground and if bushes grow up around the little pine trees their environment becomes too shady and damp. Then they are likely to be attacked and killed by one of several different fungus diseases.

In these open growing Southern forests it is a common practice to deliberately start ground fires about once every seven years. Fire burns up the dead leaves and dries out the ground, so fungi cannot grow. It kills the bushes which would compete with the pines. There is not a great deal of material to burn, so the fire is not too hot. It does not kill the tall trees. It does not kill the little longleaf pine either. Its thick mass of long needles is scorched at the outer ends, but this mass insulates the stem in the center. Therefore, the little tree is not killed by the fire or later on by the fungus. After some years in this brush-ball stage the pine starts growing rapidly and becomes a tall tree, which can be cut for lumber.

In many grassland areas it has been found that fire can be used to keep brush from growing. A fire burns the dead grass above the ground. The underground stems and roots of the grass are not killed. They send up fresh green growth in the spring. Bushes, which compete with the grass, are killed by fire, because most of their main parts are above ground. Ranchers have discovered that protecting the range from grass fires allows bushes to crowd out the grass. Bushes are not good cow feed, so fire is used deliberately in controlled amounts to keep the brush from growing.

Remember that these are special cases. In most forests, fire destroys the whole living community. Even where fire may be useful it must be used only by experts after they have made a careful study. It must be set only in the right place at the right time. There must be a crew of fire fighters ready to prevent it from spreading on to other areas where it would do harm.

Future forests. Actually, good forest management is simply a matter of treating trees as a crop. The only real difference between a forester's crop and a farmer's crop is that trees take much longer to grow. Like the farmer, the good forester must think about the next harvest when he is gathering the present one.

There is always a temptation for the owner of forest lands to cut every-

thing and make all the money he can in his lifetime. In the past, most lumber companies have operated in this way. They left entire regions bare and burned. Then they moved on to other areas. Today, most of the forest lands they destroyed are government owned. Expert foresters are hired to manage these lands, and to see to it that the forests grow again. There are also private companies that are managing their lands well. These companies must be fairly large. If they are using the block-cutting method, for instance, they must own enough land so that a new block can be cut each year for a hundred years or so. It will take that long for the first block to reach saw-log size again. The companies must be managed by men who are more interested in steady income than in making a quick dollar.

If all groups, public and private, work at the job of good forest management, there will be enough lumber for the future needs of the country. This is important to everyone. About five thousand things that we use today come wholly or partly from trees.

ACTIVITY

A study of local forests. Collect several good road maps of your region. You can obtain them from gasoline companies. See if they show any government forest areas. Write to the conservation or forestry department in your state or provincial capital. Ask for information on public and private forestry activities. Make a list of the important forest trees. Color a map to show where they grow.

Why are the forest areas on the poor land? If your region has few forest lands, why is this so?

If possible visit a forest in your area. Learn the names of the types of trees growing there. How big are they? How far apart? Are there young trees to replace the older ones? Which are the more valuable trees? What can they be used for? Is there any thinning or improvement cutting going on in this forest? Is there any fire protection?

CHECK YOUR FACTS

1. **What are the main forest regions of North America? Which one of these forest regions is nearest you?**
2. **Name several ways in which forests are useful to us.**
3. **What is the most important thing that must be done to protect growing forests?**
4. **How has bad forest management in the past robbed us of important lumber supplies today?**
5. **Under what conditions is each of the following useful in forest management: improvement cutting, reforestation, selective cutting, block cutting?**
6. **Is fire ever good for a forest? Explain.**
7. **In what ways is forestry like farming and in what ways is forestry different from farming?**

CHAPTER

17

Conservation of Wildlife

The term ***wildlife*** means all of the animals in a region. Game, fur, or food species often need protection. So do the song birds. But animals such as insects, mice, and gophers do not require protection. They take very good care of themselves.

Conservation and the environment. You learned in Chapter 12 that no living thing is independent of its environment. If a plant or animal is to survive, it must live in an environment that supplies all of the things it needs. If these conditions for survival are not present, in a given area, the plant or animal cannot live there.

Conservation, then, is not just a matter of protecting animals from hunters. Even with no hunting at all many animals die out when the land becomes settled and farms are established. Their kind of environment has been destroyed. The conservationist tries to supply all of the conditions needed for the survival of such animals. Regulation of hunting is only a part of the program.

Wolves actually benefit the deer by keeping them in balance with their

Fig. 17-1. The groundhog (woodchuck) and the cottontail rabbit. How does the presence of the groundhog help the rabbit to survive in northern environments? (Leonard Lee Rue III)

food supply. But people usually kill the wolves to protect their livestock. With natural enemies gone, the deer often multiply until they destroy their food plants and begin to starve. In this case hunting deer is helpful. If the right number of deer are killed, the rest are able to find food. Experts in conservation departments decide how much hunting is needed in each area.

Rabbits are an interesting example of the effect of environment upon species. In many northern parts of the Central hardwood forest the native type was the snowshoe rabbit. When the forests were cleared, this animal disappeared. It could not survive in open country, but the cottontail rabbit can. The cottontail came up from the south and became the common rabbit of the farmlands. It did this in spite of the rabbit hunters.

Food is not a problem with cottontails. They eat almost any plant material, so food is always present. Cover is important. There must be some sort of hiding places where they can escape from the weather and from their natural enemies. Tall grass and brush along fence rows help rabbits to survive.

It has been noted that cottontail rabbits do well in areas where there are woodchucks. These rabbits do not dig holes of their own. But they need holes as protection in the cold winter weather. In the holes they may also escape from some of their natural enemies. So the rabbits often take refuge

Fig. 17-2. Bear, bison, and elk. None of these large animals can live in settled areas. They can survive only in forest or mountain regions that are not fit for farming. (Josef Muench; National Park Service)

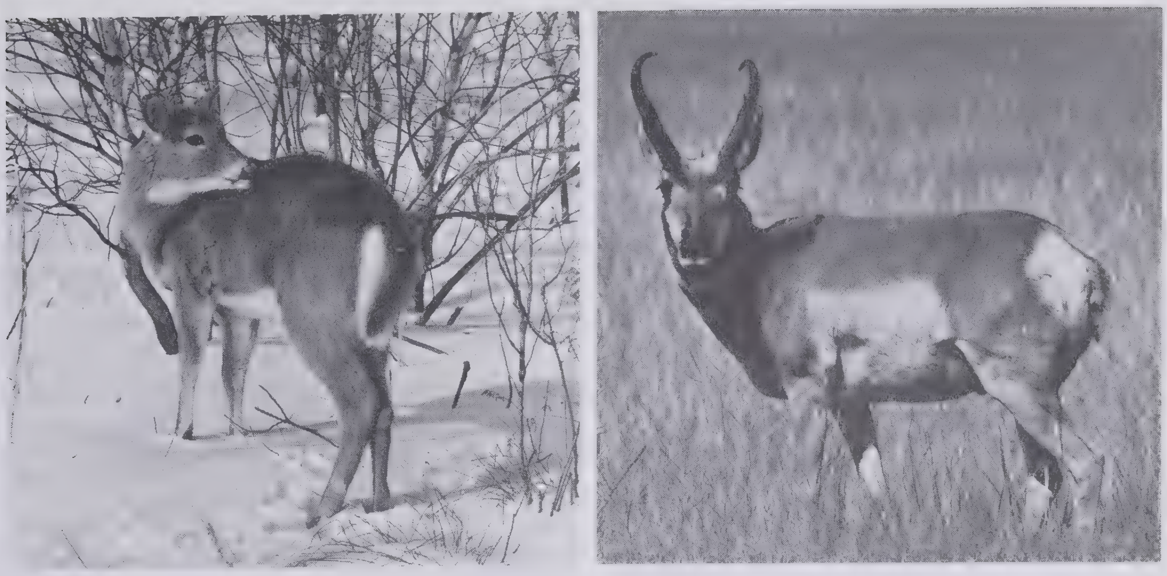


Fig. 17-3. The deer and the antelope. These are the only big game animals that can live successfully in settled country along with man. (Leonard Lee Rue III)

in woodchuck holes. Some states now protect the woodchucks from heavy hunting. Laws protecting woodchucks are really intended to benefit the cottontail rabbits.

People can encourage rabbits by setting lengths of drain tile into hillsides. One farmer placed several of these artificial woodchuck holes on his farm. During the next hunting season he killed 30 rabbits and still had too many rabbits on the land. They did some damage by chewing his fruit trees. Another farm nearby had very few rabbits on it, even though the owner seldom went hunting.

This again illustrates the basic fact of wildlife conservation: ***animals must have a total environment which favors their survival.*** In general, woodland species have had a hard time because the forest environment that favors their survival has been destroyed. They cannot live in open farm country. The cottontail replaces the snowshoe rabbit. The pheasant replaces the grouse. The fox squirrels replace gray squirrels. Meadow larks replace thrushes. Forest species survive only in the remaining forest areas.

At the same time other species have been favored by man's activities. Deer are more plentiful in this country than they were in Indian times. Cutover land produces more deer food than the great forests did. Meadow mice have become very abundant, feeding on farm crops. Foxes have also increased in numbers, feeding on meadow mice. You see, then, how man affects wildlife. By controlling the environment, he controls the species that can live on the land.

Big game animals are a conservation problem. ***Big game animals*** have the hardest time surviving in a world dominated by man. Today, succession is taking place in which man and his

tame animals are replacing the large wild animals in the communities of the world.

Bears, wolves, and mountain lions are not tolerated in settled country because they endanger farm animals. The large plant-eating animals compete with farm animals for food, so they also have been killed off. Deer are an exception. They live quite successfully in many farm areas where there is at least some woodland cover nearby.

Pronghorn antelope are also a special case. Originally they lived on the plains, eating weeds while the bison ate grass. The two types did not compete with each other. When the bison were killed off, the grass grew so tall that it crowded out the weeds. Settlers also hunted the antelope very heavily at this time. The antelope nearly became extinct. Then cattle were brought in. Over-grazing killed off some of the grass, allowing more weeds than ever to spring up. The antelope then made a comeback. They are now present in large numbers in Wyoming and other states of the cattle country. As weed eaters, they do not compete with the grass-eating cattle.

This comeback of the antelope was aided by laws to control hunting. Conservationists trapped antelope alive and turned them loose on ranges from which they had disappeared. Cooperation by the local ranchers also

Fig. 17-4. Fox, opossum, raccoon and pheasant. These are a few of the smaller game animals that can live successfully in farm country if there are some woods, hedgerows, marshes, or other kinds of cover environments for them to hide in. (Leonard Lee Rue III; Jack Dermid; Massachusetts Division of Fisheries and Game; Hal Harrison / Grant Heilman)

was an important part of this program.

Other big game animals survive only in the wilder parts of the country, where farming is not possible. Mountains, forests, drylands, and tundra are the last homelands of the remaining big game types. Hunting is allowed in such areas, but it must be regulated so that only the surplus animals are taken. They are a crop, just as trees are. Enough must be left at the end of the hunting season to maintain each type in balance with its food supply.

Bird conservation. ***Songbirds*** are not big enough to be important as food, and are useful as eaters of insect and weed seeds. In most of the United States and Canada songbirds and their eggs are protected from hunting. Only a few, such as the crow and the English sparrow are unprotected. Hawks and owls are often protected, too, because they help to control the mouse population. A few of these, such as the sharp-shinned hawk and the Cooper's hawk might just as well be hunted, for they kill many birds. But most hunters and farmers cannot tell one hawk from another, so it has proved more practical to protect them all.

Conserving the fish population. ***Fish conservation*** is based on the same general rule that governs the conservation of other wildlife: the total environment determines how many and what kinds will survive. You may have

Fig. 17-5. These hunters know that the right amount of shooting can keep the wild animals in better condition than they would be if left uncontrolled. (Vermont Development Department Photo)

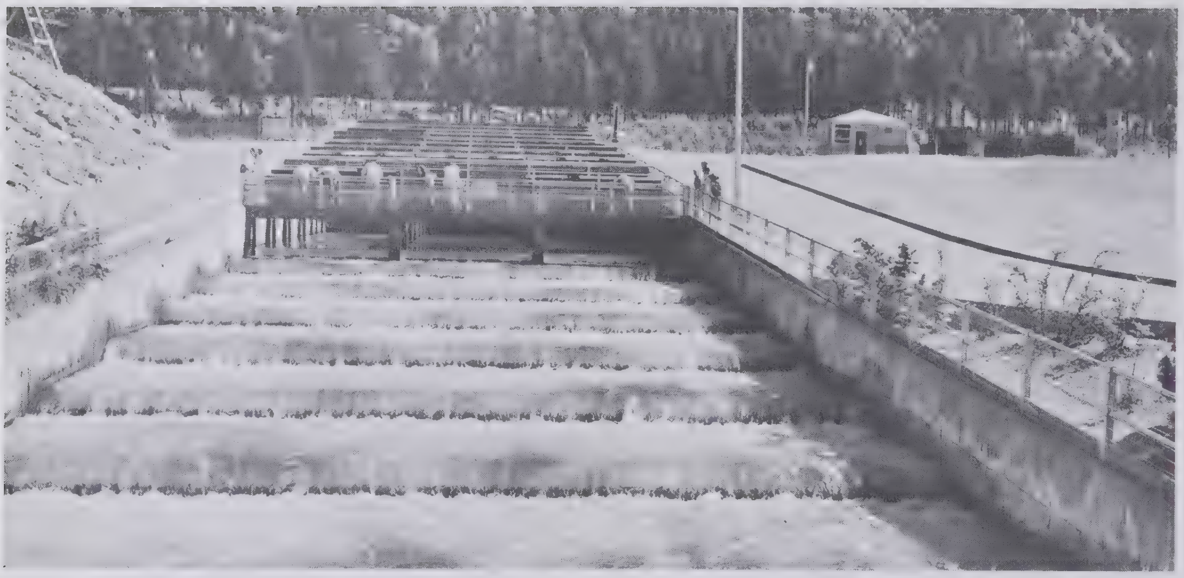


Fig. 17-6. A fish ladder. The fish jump up the ladder one step at a time and so get past the dam. (Oregon State Highway Department Photo)

heard it said that a certain lake has been "fished out." When you see a row of cottages completely lining the shore, you can easily believe that too much fishing has removed too many fish. However, fishing is not usually the reason. Man's effect on the environment has probably caused the fish to disappear.

Each cottage owner wants a clean swimming beach and boat landing at his front door. All weeds, logs, and brush are cleaned out of the water. Marshy shores are filled in. This makes a nice place for people to enjoy themselves, but the breeding and feeding areas of the fish are ruined. Minnows, which are eaten by the larger fish, feed among the plants in shallow water. Many of the larger fish like bass lay their eggs in the shallows. Pike lay theirs in marshes. Cleaning up beaches and draining the marshes destroys many of the fish even if no one ever goes fishing.

Some lakes are improved by more fishing. Sunfish, bluegills and similar panfish often breed too abundantly. There are so many small fish competing for a limited food supply that few can grow to good size. Catching some of these small fish gives the rest a chance to grow bigger. This is why many fishing laws no longer set a size limit on panfish. In certain experiments, fishing has been improved by poisoning some of the fish in a lake, leaving the rest to grow larger. This is similar to thinning stands of young trees. Introducing game fish like bass or pike into such a lake has much the same effect. They eat many small panfish, allowing the others to get larger. Fishermen enjoy catching the game fish, as well as the larger panfish.

When new species are "planted" in a lake by man, the fish used must be grown in hatcheries. Fish hatcheries are operated by local, state, and national governments. Eggs and sperm

are pressed from the bodies of fish when they are about ready to breed. Sperms and eggs are mixed together, and then the fertilized eggs are hatched in trays. After the young fish hatch, they are placed in ponds until they are ready to be planted in some lake or stream.

Dams are often used for power and for flood control. But they also prevent fish from migrating upstream in their normal way. Often fish ladders of some sort are placed around these dams. One common type is a kind of stairway of low waterfalls. The fish jump each level in turn and bypass the dam.

Trout streams are sometimes improved by planting trees along their banks. These give shade, which keeps the water cool enough for trout. Logs and brush are sunk in the edges of the water to give the fish hiding places.

Pollution has hurt the fish population in many waters, especially rivers. Cities have often dumped sewage into streams. Factories or mines pour chemicals or other wastes into rivers. Some of these substances kill the fish. Others kill the small plants and animals on which the fish feed. Soil washing off plowed fields often makes the streams so muddy that game fish cannot survive. Under these conditions fish like salmon, bass, and pike have disappeared from many streams where they were once abundant. Their place is taken by carp, suckers, and bullheads.

Sewage may kill even the carp, suckers, and bullheads. Sewage is a rich food for bacteria, which grow so rapidly they use up all the oxygen. With oxygen gone, the fish suffocate. By the time the sewage has moved farther downstream, its decay is complete. Bacterial growth slows down, and oxygen once more enters the water. Fish can live in the river from that point on downstream.

Stream pollution can be prevented if communities care to take the trouble. Modern sewage disposal plants can eliminate the dumping of sewage into streams. The right laws, properly enforced, can prevent factory pollution of streams. Good soil conservation keeps much of the mud from washing into streams. Forests on the watersheds reduce damaging floods. All of this is good water conservation also. People need clean water just as much as fish do. If streams are badly polluted they become dangerous to health, and also useless for supplying man with the pure water he must have.

Insecticides and pollution. Chemicals used to kill insects are called ***insecticides*** (in-*sek*-tuh-sides). Pollution of the environment by such chemicals has become a serious threat not only to fish but also to birds and even to man himself. Whenever man is faced with damage by some troublesome insect, he is likely to panic. So he sprays the whole area with poisons which may or may not control the pests. The result may be that the entire living community is injured.

The use of carefully selected insect sprays can be helpful in controlling pests in limited areas. Orchards and truck gardens are examples. When, however, poison sprays are used over large areas, it is hard to predict what the final result may be.

Insecticides are not all alike. Some of them lose their killing power quick-

Fig. 17-7. These fish were poisoned by an insecticide such as DDT which washed into the stream. What happens to animals which eat such fish? What can be done to prevent this kind of damage? (U.S. Department of the Interior, Water Pollution Control Administration)

ly. Others keep their killing power for a long time. DDT is a poison that remains deadly for a long period. Some other insecticides used today also have long lives. When these poisons are sprayed in large amounts, they collect on and in the surface of the soil. During rains they are washed down into streams. Here they kill fish and other small living things on which the fish feed. Thousands of fish have been killed in the Mississippi River just by poisons washed down from farmlands farther up the stream.

Eagles, hawks, and water birds may eat the poisoned fish. They store the poisons in their fat tissue but there is not enough to kill the birds themselves. However, enough poison gets into their eggs to kill the embryos before they can hatch. The eagle and the osprey are becoming rare birds just because of this action of poisons. Man probably eats traces of these poisons every day, but no one is sure just what harm this will produce in the human body in the future.

The Michigan Conservation Department brought Coho salmon into Lake Michigan some few years ago. These fish have grown well there and have furnished fine sport for fisherman. Now, however, this breed of fish is in danger. Some eggs taken from the lake have failed to hatch at all. Apparently the adult fish must have absorbed too much DDT from the lake water. Much of this poison has been traced to cities along the lake front which have had their elm trees sprayed with DDT. The cities were trying to stop the Dutch elm disease which was killing the trees and so used the DDT in great quantities to kill a beetle that spreads the disease. Some fish from the lake have been condemned for human food because they contained too much poison. The lake is 90 miles wide and 300 miles long. Is it soon to be a dead lake?

DDT is what is called a "hard" insecticide. This means that it does not break down rapidly. Some other insecticides have this same quality. On the other hand, there are several equally effective "soft" insecticides. These do their job and then break down chemically so that they disappear after a short while. They are much less likely to poison the environment permanently. Soft insecticides include Abate, Diazinon, Kelthane, Malathion, Methoxychlor, Naled (Dibron), Piperonyl, Pyrethrum, Ronnel (Karlan), Sevin, and Tedion.

What you can do for conservation. The problem of conservation of wildlife requires the help of everybody. State conservation departments can obtain

the facts. State legislatures can pass laws. But none of these measures will do any good unless everyone understands them and what is more, observes them.

When you go fishing you should know the state and local laws and use only legal types of tackle. If you catch a fish that is smaller than the legal size, throw it back in the water without hurting it. If your family has a cottage on a lake or river, be sure that they leave some of the natural plants growing in the shallow water. You might even ask your father to sink a brush pile in the water offshore to provide hiding places for young fish. The aim of real conservationists should be to do everything possible to increase the supply of fish and game.

Country people have more influence on wildlife than anyone else because they control land use. We know that pheasants live best in certain northern, grain growing areas. These areas have some ground left wild. This gives pheasants the cover they need to protect them from the winter storms. Brushy, weedy hedgerows along the fence lines give cover. Patches of grass and reeds in marshes also provide cover. When all of these hedge rows are destroyed and the marshes are drained there is no cover left for pheasants. In such "clean farming" country the birds are sometimes found dead after the winter storms. They lie next to a tree trunk or fence post where they tried to find protection. Their nostrils are plugged with balls of ice formed from their frozen breath.

Highway departments sometimes use weed killing sprays to keep brush from growing along the roadsides. This practice make the roads look better. But it destroys a lot of valuable cover that wildlife might otherwise use. Bushes and grass along fence rows and roadways are about the only good cover that is left in some areas.

If you go hunting you should, of course, abide by the laws. They are set up to allow the animals to survive from year to year. If careless people kill off too many, there can be no hunting in the future. A good hunter prides himself on making clean kills. He does not shoot until he is sure of his target. Then he aims so as to kill quickly. Careless shooting wounds animals, which get away only to suffer and die slowly. No one has the right to hunt until he has practiced enough so that he can handle a gun safely and shoot it accurately. This is not only good wildlife conservation, it is good human conservation. A true sportsman, when he hunts or fishes, never kills all of a type of animal in an area. He leaves some animals for breeding purposes and thus the next hunting season will be a good one for him and his friends. The useless and unnecessary killing of animals in an area can be very disastrous to the food chains and the balance of community life.

Hunting and fishing, of course, are not the only ways to enjoy wildlife. Many people get a great deal of pleasure from watching and studying wild animals and plants. Wildlife photography is a sport that calls for the same sort of skill as hunting with a gun. It has no closed season.

In general, the aim of wildlife conservation is to see that people in the future will have at least as good a chance as we have to enjoy the out-of-doors, and to see wild animals in their natural homes.

ACTIVITY

Local game laws. Make a study of the game laws of your state or county or town. You may write to your conservation (or fish and game) department or you may obtain the printed summary that is usually given to hunters when they buy their licenses. What are the animals of your region? Which ones are completely protected from hunting? Why? Which ones are not protected at all? Why? Are bounties paid on any species? Why? Which species are protected part of the time and hunted part of the time? How many of each species may a hunter take each year? Can you see reasons for these regulations?

Is there any disagreement among hunters, farmers, and conservationists about what hunting laws should be passed? Are any of the present laws bad ones from the conservation standpoint? If so, why have the laws not been changed?

CHECK YOUR FACTS

1. **What is wildlife?**
2. **What does the environment have to do with the conservation of wildlife?**
3. **Why did cottontail rabbits replace snowshoe rabbits in some environments? How do woodchucks "help" rabbits?**
4. **Why is conservation of big game animals a difficult problem? Where do they still live?**
5. **What would happen if there were no hunting of deer, elk, antelope, and other big game animals?**
6. **Why are hawks and owls often protected from hunters?**
7. **What do clean, sandy beaches have to do with fish conservation?**
8. **What is pollution? How can it be prevented?**
9. **What can you do to help conserve wildlife?**

UNIT 3 SUMMARY

Environment consists of everything that surrounds a plant or an animal. This includes other plants and animals. It also includes nonliving things and forces.

Sunlight is an important part of the environment. So is temperature. Plants and animals can only live within certain temperature ranges. In winter the only animals that can stay active are the warm-blooded birds and mammals. The life functions of many animals and plants slow down during cold weather. A number of animals hibernate.

Water is a factor of the environment that is needed by all living

things. Some plants and animals are adapted to live in fairly dry places. Other plants and animals must have larger water supplies. Water moves through a cycle from sea to air, to soil, and back.

Soil is an important part of the land environment. Good soil supports more plant life than poor soil. Air is also important. It contains supplies of oxygen, nitrogen, and carbon dioxide.

Besides plant roots, there are many living things in the soil. There are bacteria, protozoa, and fungi as well as various kinds of worms and insects. There may even be larger animals such as gophers, mice, and moles.

Living things get food in various ways. Green plants are foodmakers. Some animals are plant eaters. Other animals are flesheaters. Still other animals are scavengers, or parasites, or eat a wide variety of foods. Food chains exist in all communities. Living things often compete with one another. But in some cases, the presence of one living thing favors the survival of another.

Plants and animals live in natural communities. Man is part of the living community. Barriers between communities may be well marked or they may be hard to identify. Successions take place in communities. If a plant succession is not interrupted, it leads to the development of a climax community. In climax communities, living things are in balance with one another. This balance may be upset by such things as a change in climate, a fire, or the arrival of a new type of plant or animal. Then a new succession starts.

Conservation means the wise use of natural resources. Plants and animals are resources. We can produce them each year if we use the land wisely. Soil may be kept fertile by crop rotation and the use of proper fertilizers. Erosion must be avoided. The two major causes of soil erosion are running water and wind. Strip cropping and the planting of windbreaks are used to prevent erosion.

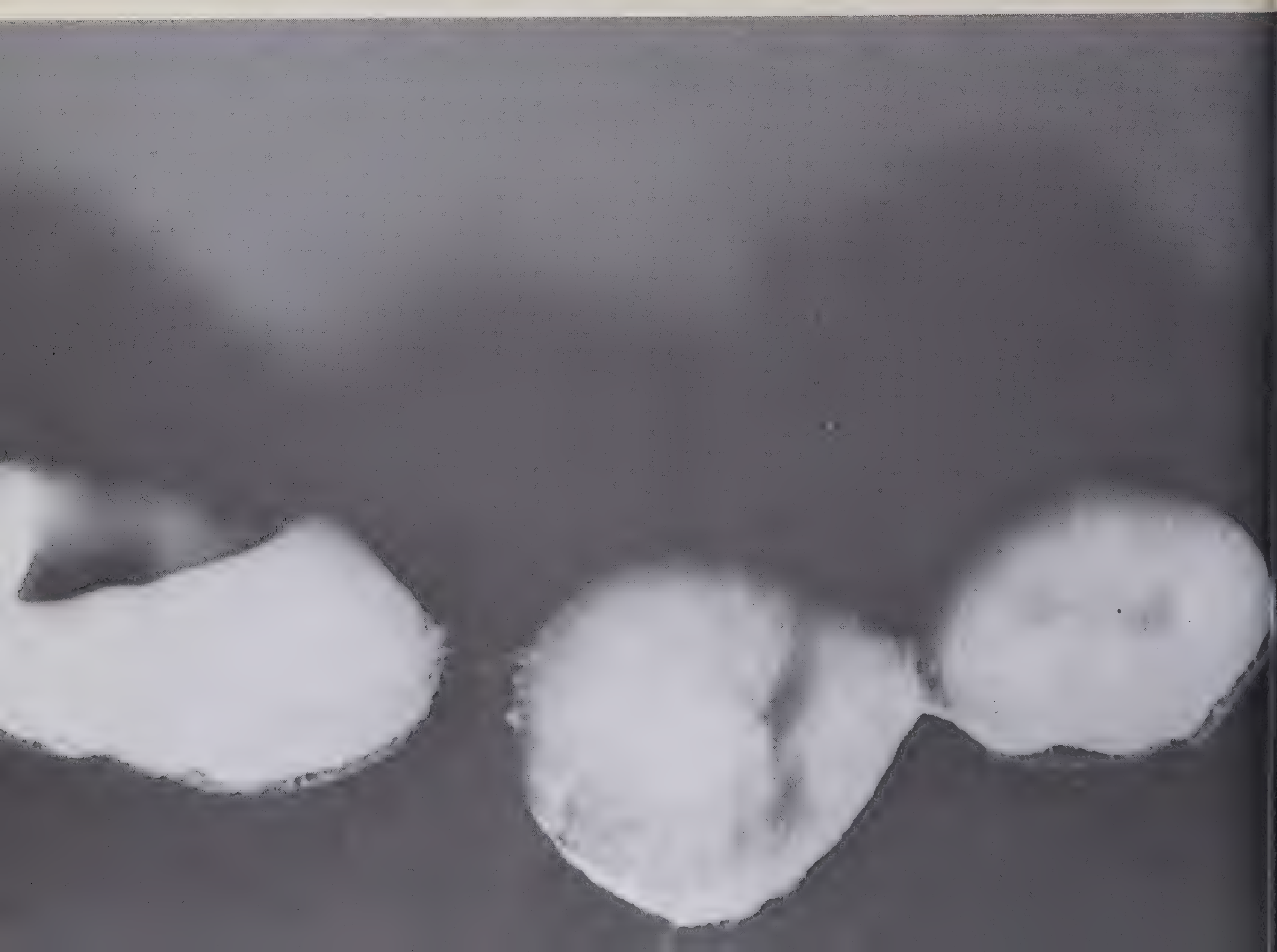
Water conservation is also important. We need water for our personal use, our crops, our animals, and our industries. Rapid runoff sends the water on its way to the oceans. Too little soaks down into the soil. Wells go dry and springs stop running. The planting of forests on the watersheds prevents erosion.

Much of our forest land is now government owned. Other forest areas belong to large lumber companies. Reforestation, block cutting, selective cutting, and fire control will keep these forests in good production. From forests we get lumber, pulpwood, chemicals, and many other products. Forest trees take time to grow, but they are really crop plants.

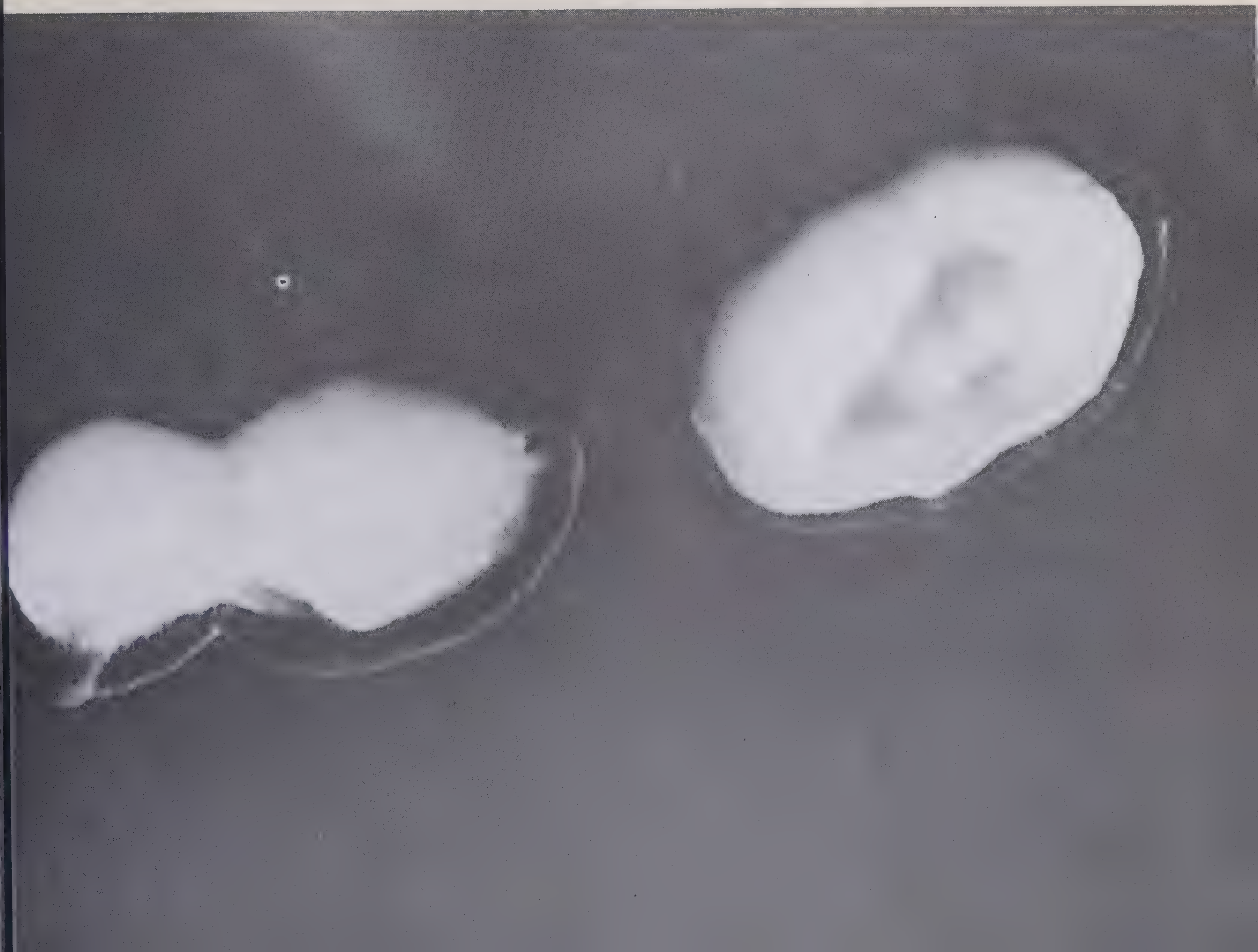
A living thing must have a favorable environment in order to survive. It must be able to make or to obtain food. If it is an animal, it must often have cover, including a safe place to raise its young. When man destroys or changes the land, various plants and animals die out. Pollution has killed the fish in many streams.

UNIT 4

Classification and Primitive Life



In this unit we will sample two different topics. First we shall see why scientists need a system for naming and classifying living things, and we shall see how this system works. Second, we shall study the most primitive types of living things. These primitive forms of life are usually too small to be seen without a microscope, and they are simple in structure. At the same time they are very important to us. In this unit you will learn why.



CHAPTER 18

Scientific Names

Suppose your teacher asked you as a homework assignment to write a description of all the living things on the earth. How long do you think this would take you? If you worked very hard you might get the job done in four or five hundred years. After all, there are well over two million known kinds of living things. This would not be a fair homework assignment for you, but it is a job which must be done by biologists. Living things need to be named and described. Then each scientist can know exactly which plant or animal another scientist is talking about when he describes his research work.

About 200 years ago a Swedish scientist Karl Linne, known today by his Latin name Linnaeus (lin-*nee*-us), actually set out to do the job of naming and describing all living things. Of course he did not finish in his lifetime, but he made a good start. What is more important, he set up a system of naming and classifying that biologists still use.

Need for scientific names. You may wonder why the naming of living things is any problem. Why not use the common names people have always had for plants and animals. There are several reasons why biologists cannot do this. For one thing, many living things have no common names. For instance, there are over 200,000 kinds of beetles alone. Only a few of them have common names.

Fig. 18-1. This bird has four common names. It is called the flicker, the yellowhammer, the high-holder, and the high-hole. (Annan Photo Features)

Fig. 18-2. Left: the familiar American robin; right: the South Island Bush Robin. What differences do you see in these two birds with the same common name? (John H. Gerard from National Audubon Society; M. S. Soper from National Audubon Society)

Most of them are just "beetles" to the average person.

Another problem is that the same plant or animal may be called by different names in different places. The same bird is called a nighthawk in some regions and a bullbat in others. There is a woodpecker with four names—flicker, highholder, high-hole, and yellowhammer. The hog nosed snake has 13 common names in the southeastern United States. A scientist might study an animal and use one of its common names. Another scientist who knew it by a different name could read the report and not be sure what animal the first scientist was writing about.

Another problem is that the same common name is often used for different living things. "Mayflower" is used for several different plants. At least three different birds are called robins (Fig. 18-2 shows two of them). This, again, leads to confusion.

Linnaeus wanted to work out a system of scientific names that would be in the same language throughout the world. He did not expect people to use these names in daily conversation. They were names to be used by scientists to identify the types they work with. Linnaeus had to decide what language to use for his name system. He used Latin, because in those days all educated men knew Latin. It was the international language among scholars.

The naming system. In Linnaeus' system, each kind or type or ***species*** *(spee*-sheez) of living thing is given a double name, in much the same way that you have a first and last name. The first word in the double name tells what group of similar species this particular kind of living thing belongs to. Such a group is called the ***genus*** *(jee*-nus*)* [plur. *genera (jen*-er-a*)*]. The second word in the double name is the name of the one particular ***species*** in the genus.

Let us take a few examples. The scientific name for a dog is *Canis familiaris*. The timber wolf is *Canis lupus*. The coyote is *Canis latrans*. You will notice that the word *Canis* is used in all of these names. This

is the Latin word for dog. It is used here as the genus name. This genus includes all the doglike animals. The second word in each case is the species name, which indicates the particular kind of doglike animal. Notice that the genus name is always capitalized. Also notice that the names are in *italic type.* In scientific writing the scientific names are usually printed in italics.

Here is another set of examples: *Felis domesticus, Felis leo, Felis tigris.* You do not have to be told that these are the cat, lion, and tiger. These animals are so much alike they were put in the same genus. Bobcats were not in this genus. They were considered different enough to be placed in a separate genus of their own, the genus *Lynx.*

These names for the cats seemed reasonable at the time. Later on, a more careful study of the animals caused scientists to change their minds. House cats are actually more like the bobcat than they are like the lion, so the names were changed. Bobcats and housecats are now placed together in the genus *Felis.* Lions and tigers are in a new genus, along with all other cats that roar. They are called *Panthera leo* and *Panthera tigris.* As you see, the naming system is flexible. It can be changed when we have new knowledge. All such changes are on record, so it is always possible to identify a species correctly even if we run across the older name in print.

The scientific name for man is *Homo sapiens.* In Latin *Homo* means man and *sapiens* means wise, or able to think. We were not very modest when we named ourselves, were we?

Who names the species? You may wonder who decides what the scientific names of the various living things shall be. The answer is that any person can name a species. Anyone who identifies a kind of living thing that has never been identified before can name it. He simply writes a careful description of the new species and gives it a name. Then he sends his description to a scientific journal to be published. The first scientific name in print is the one that is used. The name must be in the form of Latin, though it need not be made from real Latin words. There are such names as

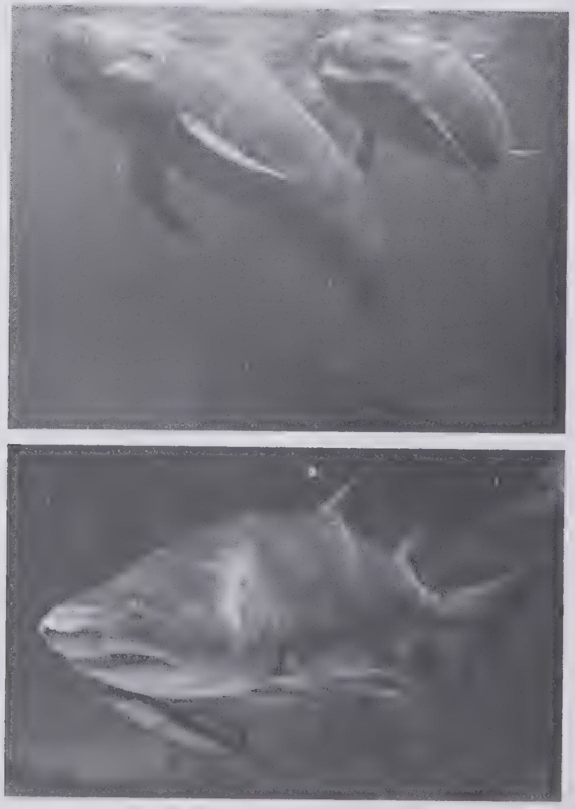


Fig. 18-3. A whale and a shark. Does their similar shape mean that they are close relatives? Which is the whale and which is the shark? (Marineland of Florida; Annan Photo Features)

michiganensis, *canadensis*, and *jeffersonianum* in use. These, of course, are not Latin words, but they have all been given typical Latin endings.

The classification system. If you were trying to describe all living things you probably would want to organize them in some way. You would not put an elephant on one page, a mouse on the next, a seaweed next, and then a beetle. The human mind remembers things best if it has them organized. In biology we *classify* living things. We put similar things in groups. A group is easier to remember than a lot of separate types.

This grouping begins with the scientific names. When we look at the name *Homo sapiens*, we know at once that man belongs to the genus *Homo*. Next, several genera that are much alike are grouped to form a ***family***. For instance, lions are in the cat family (Felidae), along with house cats and bobcats. Foxes are not in the dog genus, but are in the dog family (Canidae).

As Linnaeus looked at all of the living things, he decided that the first division he could make was to classify every living thing as either a plant or an animal. So he described two large groups—the Plant Kingdom and the Animal Kingdom.

Of course, a kingdom is a very large group, so a kingdom is divided into ***phyla*** *(fy*-luh*)* [sing. *phylum (fy*-lum*)*] Examples of the main plant and animal phyla are shown in Figure 18-5. Each phylum is divided into ***classes***, each class into ***orders***, each order into ***families***, and each family into ***genera***, and each genus into ***species***. The system is simply a method of organizing our knowledge of living things.

Here are the group names in outline form:

- kingdom
  - phylum
    - class
      - order
        - family
          - genus
            - species

Problems in classifying. You may think it is an easy matter to decide what is

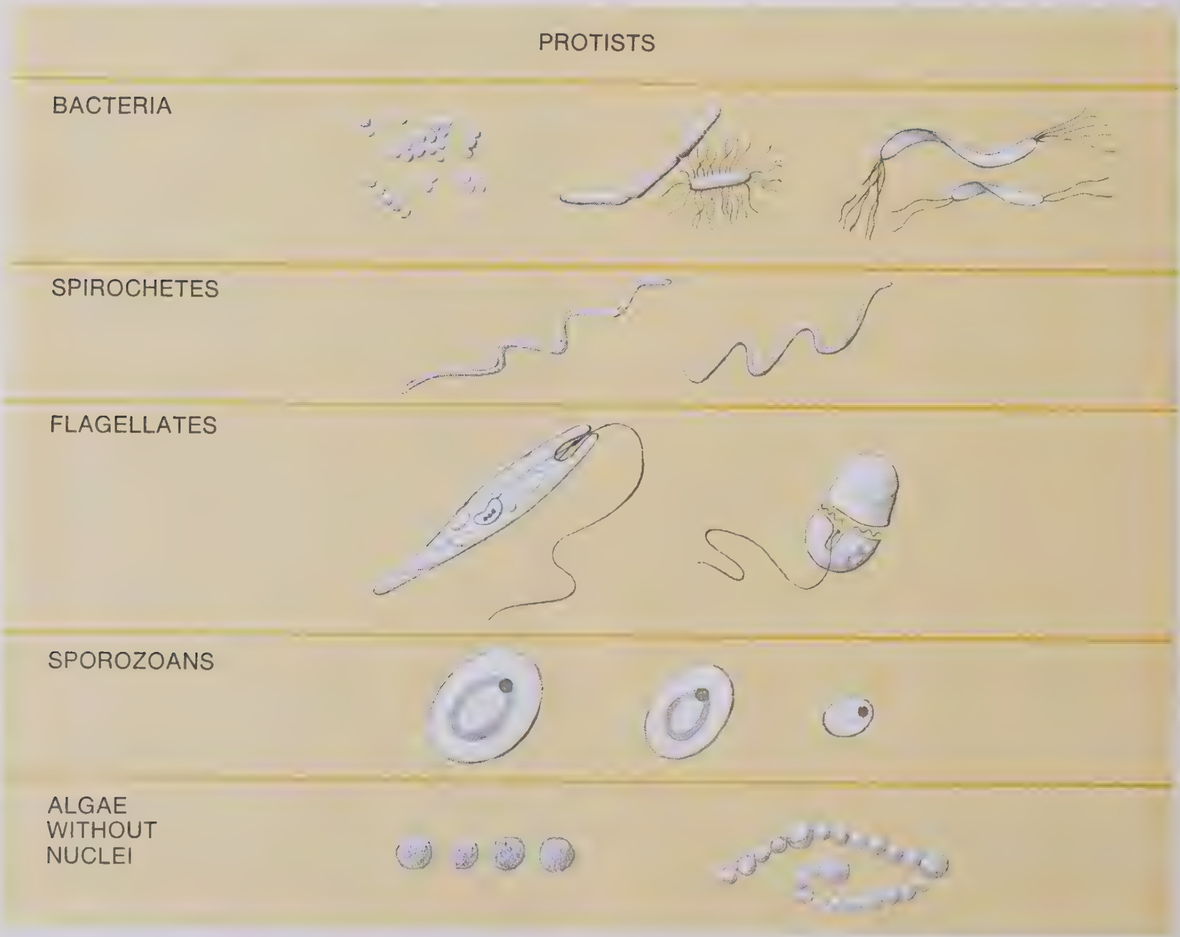
Fig. 18-4. A bat and a moth. Do the same genes produce the wings in both animals? (Leonard Lee Rue III from National Audubon Society; Walter Dawn)

an animal and what is a plant. Horses, crabs, and worms are obviously animals. Elms, ferns, and seaweeds are obviously plants. So far, so good, but what about a group like the flagellates?

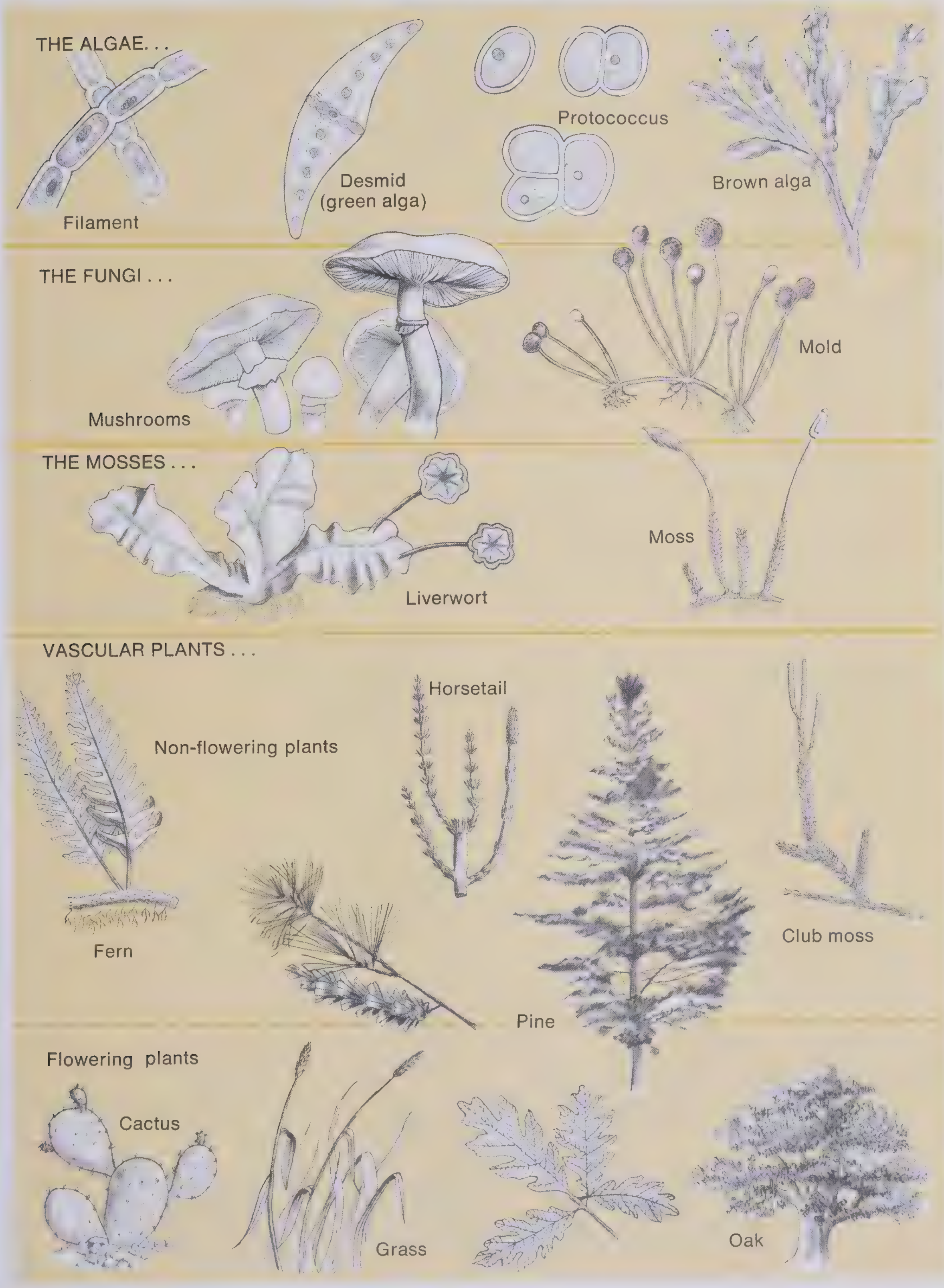
Flagellates are tiny one-celled forms which live in the water. Some of them feed on particles of food the way animals do. Some have chloroplasts and make their own food, like plants. Some absorb dissolved food materials the way the decomposers do. There are species of flagellates which feed in more than one of these ways. All this makes it hard to say that as a group flagellates are either plants or animals. Bacteria and some other simple types are also hard to classify.

Many biologists believe it is time to stop trying to put all living things in just two kingdoms. They would keep the plant kingdom and the animal kingdom for types that are clearly plants and animals. But they would add a third kingdom—the kingdom Protista. In it they place all simple types that are not clearly either plant or animal. They call these simple types the *protists (proh-tists)*. Some biologists say we should have four or five kingdoms. In this book,

Fig. 18-5. A few of the kinds of living things which are found in the protist kingdom.



THE PLANT KINGDOM



THE ANIMAL KINGDOM

however, we shall use the three kingdom system. The types we call protists are all simple, and they are types that might be called either plants or animals. Many of them are on the border line between plant and animal life.

The basis of classification. The idea behind the classification system is to show actual relationship among groups. A dog and a wolf are close relatives. Their genes are nearly alike. They evolved from the same ancestors as the result of natural selection. We show this close relationship by placing them in the same genus. A fox is not as closely related to the dog as the wolf is, yet dogs and foxes are a great deal alike. We show this degree of relationship by putting them in the same family but not in the same genus. We use this same sort of reasoning when we say people are first, or second, or third cousins. Such an arrangement shows how closely related they are.

In trying to decide how to classify living things we look at their basic structures. Two species may look alike and yet not be closely related. A whale certainly looks like a fish, yet a study of its structure shows that it is a mammal. It has the same warm blood, lungs, type of heart, type of reproduction, and many other features that are found in the land mammals. It evolved from ancestors that lived on land. Only its shape is fishlike. This shape is simply an adaptation to life in the water.

Look at Figure 18-4. Would you say that the bat and moth are related because they both have wings? Before you answer this question notice that the bat's wings contain the same bones that are found in your hand. The moth's wings are formed by wide, thin folds of its outer body covering. The whole inside structure of the moth shows that it is an insect. The bat's structure shows that it is a mammal. This means that the bat and the moth are not closely related. In fact, the bat is more closely related to you than it is to the moth!

In the following chapters we shall study the main groups of living things. Most of the time we shall deal only with phyla. In only a few cases will we talk about smaller groups.

ACTIVITY

An experience in classification. Collect as many examples of plants and animals as possible. These may include specimens already present in the classroom and others gathered from the school grounds and from around the neighborhood. Weeds, tree leaves, grasses, worms, insects, spiders, mounted birds or anything else available will do. Next, try to decide how these specimens should be placed in classification groups. Try to base your groupings upon differences and similarities in actual physical structure. Place the groups in different locations around the room. What difficulties do you have in deciding how to group your examples? Is it easy to get everyone to agree? Do you suppose scientists had similar troubles in setting up their classification system? Using reference books see how much your classification is like the one the scientists use.

CHECK YOUR FACTS

1. Why are scientific names needed in the study of living things?
2. Who started our present system of scientific names?
3. What makes up the scientific name of any one kind of living thing?
4. Why was Latin used for scientific names?
5. List in order the groupings we use to classify living things.
6. Suppose we had never discovered the microscope. Would we then have any trouble classifying all living things as plant or animal? Explain.
7. How do we decide in what group a species belongs?

CHAPTER

19

Bacteria—Important Protists

The **bacteria** (bak-*teer*-ee-uh) [sing. bacterium] are a large group of one-celled living things. If you like the idea of the kingdom *Protista*, you can think of bacteria as a phylum of the protist group. This is where they belong because they are so primitive in structure.

Bacteria are smaller than most one-celled forms of life. But what they lack in size, they make up in numbers. For bacteria are found wherever living things exist. Many of these bacteria are of great importance. Life as we know it could not continue without some of them. The living world could get along without man, but not without some of the bacteria. As you read this chapter, see if you can discover why this is true.

You may have learned to think of bacteria as a group of germs. And to be sure, some bacteria are just that. They cause some diseases in man, and in the plants and animals that men raise. But many other bacteria are very useful.

As we have said, bacteria are very small. They are much smaller than the nucleus of an average plant or animal cell. You need a powerful microscope to see them. Thirty trillion bacteria of average size weigh only an ounce. That many cells of ordinary size might make up a 12-year old girl.

Until about three centuries ago people did not know there were such things as bacteria. We are now aware that these little protists are all around us. They are in the air, in the soil, in lakes, ponds, streams, and oceans. There are bacteria on our floors, walls, ceilings, and furniture. They are on your skin, and in your mouth and intestines.

Characteristics of bacteria. Typical bacteria occur in three common shapes. Some of them are round, some are rod-shaped, and some are spiral (Fig. 19-1). Bacteria are all one-celled, but sometimes they are grouped together in pairs, chains, or clusters. A large group of bacteria is called a ***colony.*** A colony can become large enough to be seen without a microscope.

A bacterium has a cell wall. Just inside this wall is a cell membrane. The inside of the cell is filled with protoplasm. There is a chromosome, but it is not contained in a nucleus.

In some species of bacteria, one or more very thin, hairlike structures stick out from the cell. These hairlike parts are called ***flagella*** (fluh-*jell*-uh). They lash about in liquid like tiny whips. This causes the bacteria to move. But bacteria never go far in one direction. They just seem to move

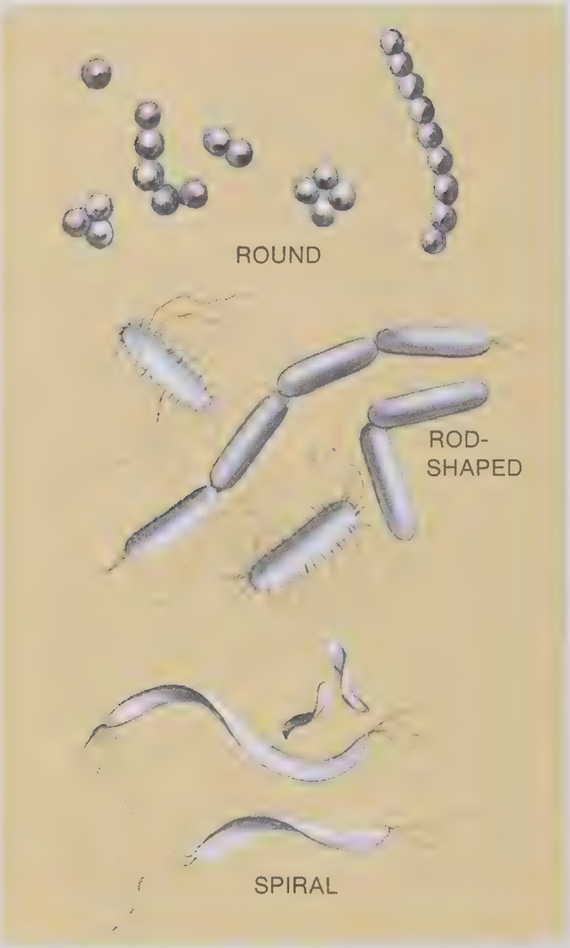


Fig. 19-1. The three common shapes of bacterial cells. Which ones show flagella?

about in the same general area. The movement, however, may bring them in contact with food molecules.

Some bacteria are producers. Some species of bacteria contain a substance similar to chlorophyll. These bacteria carry on photosynthesis. They use the energy of sunlight to make food. They are not green, however. Many are purple.

Another group of bacteria makes food in quite a different way. They do not get their energy from sunlight. They get it from chemicals. For example, one type combines oxygen with iron to get energy. Others use sulphur. The energy is then used to combine water and carbon dioxide and make food.

You can see, then, that it is not quite correct to say that green plants make all of the food in the world. Bacteria also make food. Some use sunlight and some do not. The food these bacteria make is passed along in food chains just as other foods are. However, the amount of food made by bacteria is very small compared to that made by green plants.

Most bacteria are consumers. Bacteria usually get their food readymade. Among these are the bacteria of decay. When something decays, the decay is due to bacteria living in the material. They give off digestive juices

Fig. 19-2. Highly magnified bacteria showing flagella. (Walter Reed Army Institute of Research, Walter Reed Army Medical Center, Washington, D.C.)

which dissolve the material. Then they absorb this dissolved food material through their cell membranes.

Each species of bacterium is adapted to live in some special type of environment and to use some particular food. Some bacteria need oxygen. Some do not. Some are actually killed by oxygen, so they must live deep inside their food supply—in such places as the mud of a lake bottom or inside the body of a rotting animal. Some use the same sorts of foods that we do. Others use all sorts of other foods, like humus, wood, cloth, petroleum, soap, manure, dead animals, and many others. In fact, every substance in nature that has possible food value is used by some kinds of bacteria. This is what makes bacteria so important. In their activity as decomposers bacteria break down everything and as a result the elements can be used over again.

If dead things did not decay, the living world would be in trouble. When green plants needed simple substances to build up into food materials, they could not get them. The needed materials would be tied up in dead bodies. Remember that elements in protoplasm are used over and over again by living things. Decay bacteria play an important part in breaking down dead substances into forms that green plants can use. Of course, they do not do this to be helpful. They are simply using dead things as food.

The nitrogen cycle. ***The nitrogen cycle*** is one example of how important bacteria can be in the day to day events of the living community. Decay bacteria in the soil break down proteins in dead material and produce nitrogen compounds called ***nitrates*** *(ny-*trates*)*. Green plants in turn use these nitrates to make more proteins. When green plants die, bacteria again begin their work of decay and release nitrates, and the cycle starts over again. If the plants are eaten by animals the result is not much different. Animal wastes and the bodies of dead animals are decayed by bacteria to release nitrates into the soil.

There is a bigger nitrogen cycle also. The air is nearly four-fifths nitrogen gas, but most green plants are not able to use this gas. Certain other bacteria, different from bacteria of decay, take nitrogen directly from the air and use it to build their own protoplasm. Later this nitrogen is released into the soil in the form of nitrates. These bacteria are called *nitrogen-fixing bacteria.* Some of them live in the soil. Other nitrogen-fixing bacteria live in the roots of plants. They obtain glucose from the plants, and the plants obtain nitrates from the bacteria. This is another example of cooperation among living things.

Plants of the pea family are very likely to have nitrogen-fixing bacteria in their roots. If you pull up a clover or alfalfa plant you may see swellings on the roots where these bacteria live. Farmers often plant clover, soybeans, or alfalfa for this reason. Not only do the leaves and stems of these plants make good food for animals, but the bacteria in their roots add considerable quantities of nitrates to the soil.

A third kind of bacteria break down nitrates in the soil and release free nitrogen gas into the air. In this way the nitrogen makes a complete cycle, starting in the air and coming back to the air in the end. Figure 19-3 will help

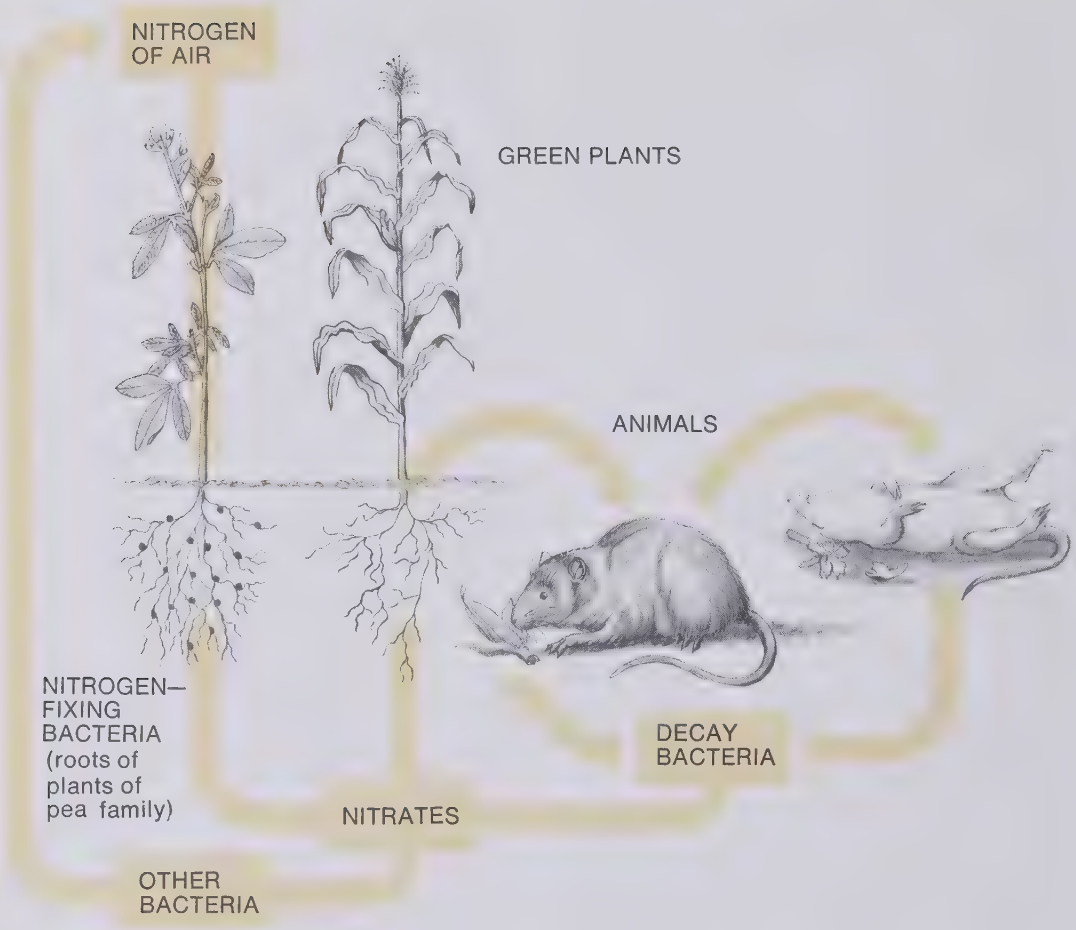


Fig. 19-3. The nitrogen cycle. The nitrogen supply is important to living things. Nitrogen forms a part of proteins, nucleic acids, and ATP. Could we live without nitrogen?

you to understand the nitrogen cycle.

The action of nitrogen-fixing bacteria is the most important way in which nitrogen from the air is combined to form compounds. It is not the only way, however. In water communities some of the algae can also fix nitrogen. In addition, electric discharges such as lightning cause nitrogen to combine with oxygen to form compounds in the air. After some other chemical changes these compounds become nitrates. Small amounts form during thunderstorms and are washed into the soil by falling rain.

Reproduction of bacteria. To live actively, bacteria must have moisture, food, and suitable temperature. When conditions are not right for bacteria they become inactive. Some can remain alive on dry surfaces for a long time. When moisture and other conditions become right these bacteria soon begin to grow and reproduce.

Activity for bacteria is a matter of feeding, growing, and reproducing. If

the conditions of life are good, bacteria reproduce very rapidly. Each cell grows to full size and then divides. The two new cells in turn grow and divide. Divisions may take place as often as every 20 minutes. This means that a single bacterium can produce millions of offspring in a few hours. At this rate you might think the world would soon be full of bacteria. This does not happen because their environment never stays perfect for very long. They may use up their food supply, or they may become too crowded. When they are crowded their own waste materials slow down their growth. Also, bacteria have natural enemies which feed on them. You will learn about these natural enemies in the next chapter.

If the environment is unfavorable some bacteria form spores. A bacterial spore is a tiny cell developed within the parent cell. Often there is only one spore to a cell. A spore can continue to live when conditions would kill the parent cell. When the environment becomes favorable again, a spore can develop into a full-sized bacterial cell.

Food spoilage. Since bacteria are present everywhere, any food material will soon decay. If we wish to prevent decay, there are several methods we can use. *Refrigeration* does not stop decay, but it does slow it down. All chemical changes are slowed as the temperature is lowered. Food will keep about four times as long in the refrigerator as it will at room temperature. *Freezing* does not kill bacteria, but it stops their activity almost entirely. Frozen foods will keep for many months.

Salting preserves foods. Bacteria cannot live in a very salty environment because water is drawn out through their cell membranes. *Sugar* is sometimes used to preserve foods for the same reason. Often foods are *pickled* in spiced vinegar, salt, and water to keep bacteria from spoiling them.

Drying is another way of preserving foods. Without water, bacteria cannot grow. Crackers, flour, and breakfast cereals keep for this reason. What about raisins? Cloth and wood, as well as food, will rot if they stay wet for too long.

When we *can* foods we do two things. We cook the food at a high temperature to kill the bacteria already present. We use steam pressure cooking because ordinary boiling will not kill all of the bacterial spores. Such spores

Fig. 19-4. The swellings on the roots of this soybean plant contain nitrogen-fixing bacteria. Both the bacteria and the soybean profit. What does each get from the other? (USDA Photo)

are not always present, but they can be. If high enough temperatures are used it will not matter. Finally we seal the can to keep any other bacteria from entering and to keep out oxygen. If food has been properly canned it will keep for years.

Disease bacteria. Some bacteria do not wait until we are dead to start using us as food. They move right in while we are still alive. In other words, they are parasites. Many serious diseases are caused by bacteria, including tuberculosis, pneumonia, and diphtheria. We shall study disease in Chapter 48.

Practical uses for bacteria. Bacteria use a great many different materials for food. In doing this they produce many kinds of waste products. These waste products are often very useful to man. *Vinegar* is a good example of this. It is made by allowing certain bacteria to live in a material containing alcohol. Hard cider is often used. The bacteria change the alcohol into acetic acid. This acid gives vinegar its sour taste.

Many kinds of *pickles* are made through the use of bacteria. Cucumbers are placed in salty water, causing some juice to pass out of the cucumbers. This juice contains sugar. Bacteria change this sugar into an acid called lactic acid. The lactic acid prevents other bacteria from growing, so the pickles do not spoil.

Sauerkraut is made in much the same way. Bacteria change the sugar of the cabbage juice into lactic acid. As long as air is kept out, the sauerkraut does not spoil. No decay bacteria can live in the acid.

Silage (sy-lij*)* is made in the same way as sauerkraut, except that chopped corn plants or chopped grass are used instead of cabbage. The farmer uses a machine to chop the plant materials and blow them into a tall round bin called a silo. Bacteria produce lactic acid, which preserves the chopped plants, forming silage. Silage is used as feed for farm animals, especially dairy cows. If you travel through dairy country you will see one or more silos connected to most barns.

Bacteria have a part in the making of *cheese* from milk. In fact the souring of milk is a bacterial action. Cottage cheese is made directly from sour milk. Other cheeses are made by first adding an enzyme to milk. This forms solid chunks, called curds, very much like those which form when milk sours. Then these milk solids are acted upon by bacteria to produce cheese. The temperature and other conditions are adjusted so that only certain bacteria can grow. Thus the cheese maker controls the kind of cheese produced.

Bacteria are useful in producing several other foods by changing them in some way that will make them better to eat. These include black tea, coffee beans, vanilla pods, and cocoa beans, from which cocoa and chocolate are made. Some *vitamins* are produced by bacteria when they are grown in a soupy material containing ground-up grains. After the bacteria have grown for a while, the vitamins are removed from the liquid and added to a number of foods.

Many cities eliminate sewage with the help of decay bacteria. This is discussed in Chapter 49. Decay bacteria

Fig. 19-5. Cheese making in Switzerland. The large wheels are kept in this warm room for four to six weeks. Bacteria grow in them and give the cheese its special flavor and texture. (Swiss National Tourist Office)

are also used in producing several plant fibers, including flax (used for linen), hemp (used for rope), and jute (used for burlap). In making linen, the flax stems are allowed to decay slightly under water. The decay loosens the fibers from the other tissues in the stem. The fibers can then be separated out and made into cloth. This method of separating fibers from the stem is called *retting*. Jute and some kinds of hemp fibers are also freed from their stems by retting.

Industry is using bacteria more and more in the production of useful chemicals. A list of some of them will give you an idea of how many there are. These chemicals include acetone, methyl alcohol, butyl alcohol, propionic acid, citric acid, vitamins, and several enzymes. In each case the chemical is formed by allowing bacteria to grow in some food material such as molasses, sawdust, or starch. The useful product is usually formed as a waste by the bacteria during their growth. The chemicals just mentioned are used in the making of many products, such as industrial solvents, soft drinks, dyes, plastics, leather, explosives, perfumes, drugs, and anti-mold materials for bread.

ACTIVITY

Growing bacteria. Your teacher will use a steam pressure cooker (scientists call it an autoclave) to cook up a batch of nutrient agar in a flask. This flask is kept closed by a wad of cotton and sterilized in the pressure cooker. He will also sterilize several Petri dishes and

their covers in an oven or in the pressure cooker.

Place the Petri dishes on the table. Quickly lift the lid of each one, pour in some nutrient agar and close the lid. When the dishes have cooled you will find that the agar has turned solid like gelatin desert. it contains food that bacteria can use but there are no live bacteria on it. Why not?

Set two or three dishes aside just as they are. These are the controls. Use the rest of the dishes to grow bacteria in. There are many different things you can test on the agar. Suggest a few of these things to your teacher. For instance, you can touch the agar with your fingers. You can sprinkle floor dust on the agar. You can sneeze on it. There are many other possibilities. Keep all of the dishes in a warm place for several days. An incubator is best if you have one. Under these conditions any bacteria which are able to use the food in the agar will begin to multiply. Soon there will be so many bacteria that you can see spots on the agar. These are bacterial colonies.

Which cultures show the greatest number of bacteria? Which show the least? Are there any on the controls? Why did we have controls?

Most of the bacteria you have grown are harmless, but some could be disease-causing types. Drop all of the dishes in boiling water before cleaning them. Why should you bother to do this when the same kind of bacteria are around you all the time anyway? Do you ordinarily encounter such large numbers of them all at once?

Observing bacteria. Fill a glass breaker half full of lima beans. Fill the beaker with water and let it stand a few days. The unpleasant odor that develops will be a sign that bacteria are at work. Make a temporary mount, using a drop of this bacteria-filled water on a microscope slide. Bacteria are very tiny. Even under high power they will not look very large. Make another mount in the same way, only stain the bacteria with a solution of methylene blue.

CHECK YOUR FACTS

1. **Describe the shape, size, and structure of bacteria.**
2. **What are three ways in which bacteria obtain their food?**
3. **What must decay bacteria do to solid foods before they can absorb them?**
4. **Why do we say that decay bacteria are very useful?**
5. **Suppose a bacterium divides in twenty minutes. Then these two cells divide in another twenty minutes, and so on. How many bacteria would there be at the end of one hour? Two hours? Four hours? Eight hours?**

6. Where is the earth's main free nitrogen supply? What form must nitrogen be in if plants are to use it?
7. Three groups of bacteria were described in the nitrogen cycle. What does each of them do?
8. What is it about each of the following processes that prevents food from spoiling: refrigeration, freezing, salting, drying, canning.
9. Name several ways in which man uses bacteria.

CHAPTER 20

Protozoa and Other Simple Types

There are four groups of simple living things that have been called ***protozoa*** (pro-toh-*zoh*-uh). Today, one of these classes is sometimes put with the protists. So are some of the flagellates that have both animal and plant-like ways of getting food. *Ameba*, of course, is clearly an animal cell. *Ameba* moves about freely and seeks its food like an animal. It cannot make food because it has no chlorophyll.

The Ameba phylum. You have studied *Ameba* in Chapter 5. *Ameba* and its relatives move by a flowing of their protoplasm. They do not have flagella or other swimming structures. They take in food by wrapping around it.

Some types of ameba-like living things that live in oceans have shells around their one-celled bodies. Some of these shells are very beautiful when seen under the microscope. These little animals are very common in the sea. When they die, they settle to the bottom and form a limy mud. It

Fig. 20-1. An *Ameba*. What parts can you identify? (Walter Dawn)

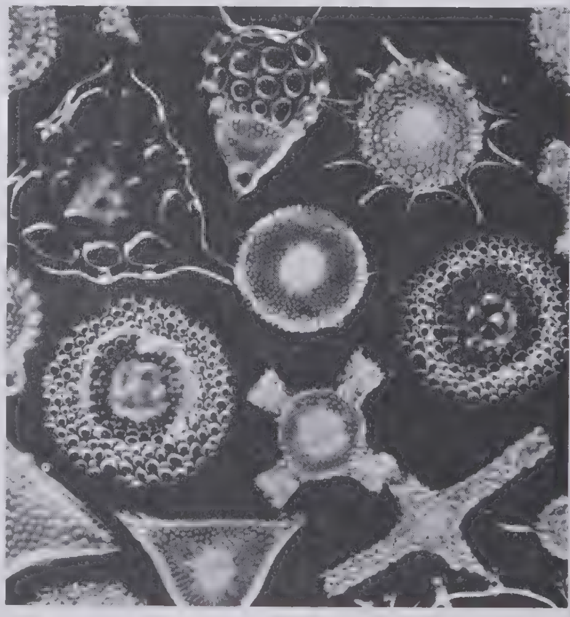


Fig. 20-2. Highly magnified shells of various protozoa in the *Ameba* group. So many of these may collect on the sea bottom that they harden into thick layers of limestone. (Struwe/Monkmeyer)

may finally harden into chalk or limestone. Your teacher writes on the board with these skeletons. Perhaps there are some of these shells in the walls of some public building in your neighborhood. It is believed that the oil we pump out of wells was also formed partly from the bodies of these protozoa. As they decayed in the mud, oil from their protoplasm gradually changed into petroleum.

Fig. 20-3. *Euglena,* a member of the flagellate group. In what ways are flagellates like plants? In what ways are they like animals? (Courtesy Carolina Biological Supply Company)

The flagellates. Another phylum of protozoa is made up of species which swim with flagella. Some types have one flagellum. Others have several. Because of this characteristic they are commonly called the flagellates.

A very common species of flagellate living in fresh water is ***Euglena.*** Figure 20-3 shows the structure of *Euglena.* As you see, it has a long body with a flagellum at the front end. *Euglena* swims through the water by vibrating this flagellum. The cell contains a nucleus and usually several chloroplasts. There is a red eyespot near the front end. This is not an eye that sees things. It is simply a structure that is sensitive to light. Euglena is able to tell light from dark with this eyespot. Would *Euglena* swim toward or away from the light? Why?

Euglena is able to make its own food with its chloroplasts. It can also take in food molecules from its environment by absorbing them through the cell membrane. Some other flagellates have another way of feeding. They take in solid particles of food and digest them inside the cell. This food is not taken in through just any part of the cell membrane, as in *Ameba.* It enters through a definite mouth opening at the front end of the cell. The dent in the front end of *Euglena* is such a mouth opening, but *Euglena* never seems to use it.

So you see that some of the flagellates have three ways of feeding. Some of them can make food, like the green plants. Some can eat solid foods, as the animals do. Some can absorb dissolved foods like the bacteria and many types of the fungi. Some species use all of these methods. Others use only one or two of them.

Some biologists believe that all of the true plants and animals developed from flagellates long ago. You can see how this may have happened. Through natural selection some flagellates came to depend entirely on photosynthesis and finally developed into green plants. Others specialized in absorbing dissolved foods. These would have developed into fungi. Still others specialized in searching for food and eating it. The Animal Kingdom could have started from flagellates in this way. Even today the

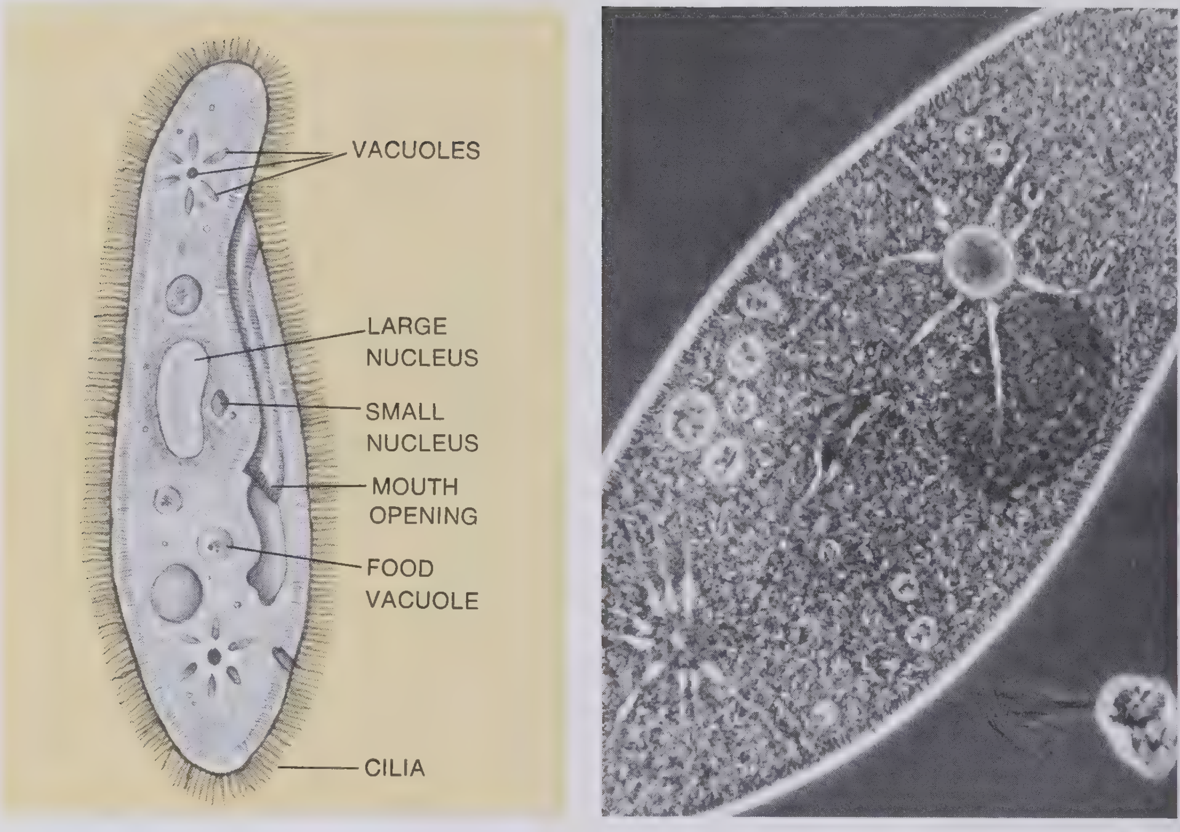


Fig. 20-4. *Paramecium.* This is a large ciliate and is so complicated that it needs the large nucleus just to control the cell's activities. The small nucleus carries the heredity factors. (Walter Dawn)

sperms of most higher animals look very much like flagellates.

The ciliates. In almost any pond the most common protozoa of all are members of the ***ciliate*** group. ***Cilia*** are simply very short flagella, and a ciliate's body is usually covered with them on all sides. This gives the ciliates a better swimming ability than the other protozoa. A very common example of the ciliate group is ***Paramecium*** (par-a-*mee*-see-um) [plur. *Paramecia* (par-a-*mee*-see-uh)]. In Figure 20-4, see how cilia cover the entire outside of its body. They are not just around the edge as shown in the diagram. They beat the water like little oars sending *Paramecium* through the water.

If you look at a live *Paramecium*, you will see that there are definite front and back ends of the cell. Also, that the cell has a more or less permanent shape which does not change as *Ameba* does. Along one side of the cell is a ***mouth opening.*** Cilia wash water that contains bacteria and other small bits of food through this mouth opening and into the cytoplasm. In the cytoplasm bits of food collect into a little ball with a membrane around it. This is called a ***food vacuole.*** Several food vacuoles may be present at the same time. The food in such a vacuole is digested and ab-

sorbed by the cytoplasm. Materials that cannot be digested are forced out of the cell through a weak spot in the cell covering not far from the mouth opening.

Something else to look for in *Paramecium* is the pair of star-shaped vacuoles, one near each end of the cell. These vacuoles act like pumps to get rid of extra water that comes in through the mouth opening and the cell membrane. Many protozoa have vacuoles of this general type. As vacuoles fill with water they get bigger and bigger. Then one of them contracts suddenly and the water is forced out through an opening in the cell covering. In *Paramecium*, one vacuole contracts while the other vacuole fills with water. Then the second vacuole contracts while the first takes on water again.

Paramecium is very large for a single cell. If you hold up a drop of water containing several *Paramecia* you can just barely see them moving around. They look like tiny white specks in the water. Most other cells cannot be seen without a microscope. When you examine *Paramecium* under the microscope you soon see that it is not as simple as *Ameba*. Besides the things we have mentioned, *Paramecium* usually has more than one nucleus. In fact, *Paramecium* and its relatives are just about as complicated as it is possible to get and still exist as one cell. The larger, more complex living things all have bodies which are made up of many cells.

Spore-forming protozoa. The fourth group of protozoa are the ***spore-formers.*** Members of this group cannot move about, the way other protozoa do. They received their name from the fact that they almost always form spores. A cell divides into many tiny cells, which can be scattered to spread the species into new environments. The spore-formers are all parasites which live in animals. The best known are the ones that cause malaria in man. As you probably know, they are carried by certain mosquitoes, so their lack of ability to swim does not matter. The mosquitos carry these parasites wherever they go.

Cyst forming. Since most protozoa live in water they have a problem when the water dries up. How can they live until rain comes and fills the pond again? Many protozoa solve this problem by forming a heavy wall around themselves. This is called a ***cyst.*** A protozoan inside a cyst cannot take food, nor can it be very active in any other way. The cyst keeps the cell from drying out. When the cyst has water around it again, the protozoan breaks out and resumes an active life.

Importance of the protozoa. As we have said, some protozoa form limestone and oil deposits. But when we speak of the importance of a group of living things we do not mean just their importance to man. We are interested in how they fit into the whole living community. What is their effect on all the living things around them?

We do not really know how important the protozoa are. They probably are links in a great many food chains. They are common in all of the oceans, streams, ponds, and lakes. There are a great many of them living in damp soil. They feed on bacteria, small bits of plant material, and smaller proto-

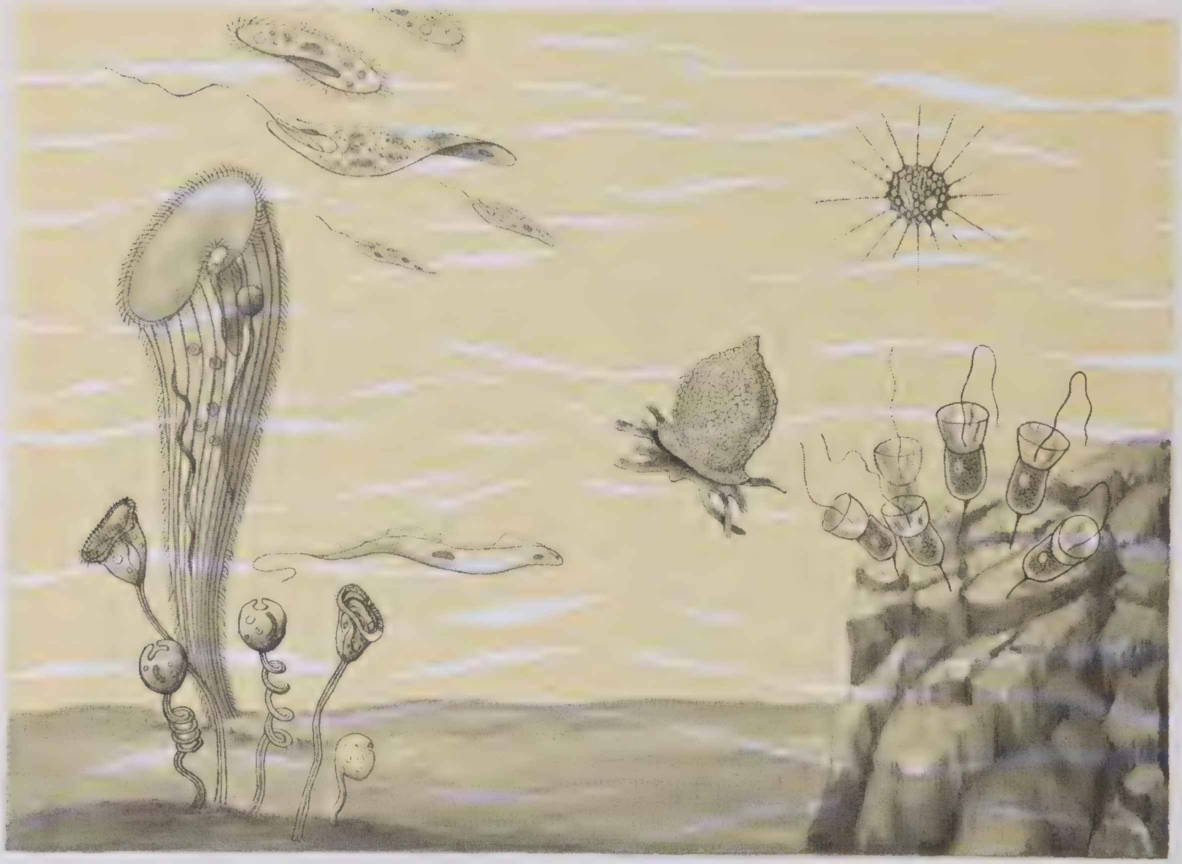


Fig. 20-5. Some of the common types of protozoa.

zoa. They, in turn, are eaten by larger water animals. The fish that you eat may have eaten something which ate protozoa, putting you in the same food chain with these tiny living things.

A few diseases of man are caused by parasitic protozoa, including some very bad ones. Malaria, African sleeping sickness, and amebic dysentery are three of the most troublesome. Besides these dangerous protozoa, there are many others that may live in us without doing any harm at all. One type of protozoan lives in the intestine of termites. These tiny protists help to digest the woody material that termites eat. Termites would not be able to digest wood without the help of these protozoa.

Protists in general. There are other simple types that can be classified as protists. The protist kingdom might be set up something as follows:

1. The bacteria which have no nuclei.
2. Some types that are even smaller than bacteria but are like bacteria in certain ways.
3. From the protozoa, the spore-formers, some of the flagellates, and a few colonial types that contain chlorophyll.
4. The blue-green algae, which are more primitive than the other algae.

Like bacteria, blue-green algae do not have nuclei in their cells.

5. Some of the primitive types among the so-called fungi.

Living things like these must have been on the earth long before any of the higher forms of life appeared. The small size and lack of a nucleus in bacteria and some other protists is especially interesting. These are primitive traits.

The viruses. We now come to a group of substances that are a real puzzle. These are the ***viruses.*** They are so primitive that we cannot decide whether to call them living or nonliving. They are not organized into cells, and they do not carry on all the life activities. They are too small to be seen under an ordinary microscope. Only a special instrument, the electron microscope, can make them visible. Electron microscopes are large, expensive, and difficult to use. They are found only in the larger research laboratories.

Fig. 20-6. Malaria parasites in red blood cells. What other diseases are caused by protozoa? (Walter Reed Army Institute of Research, Walter Reed Army Medical Center, Washington, D.C.

A virus is built very much like a small piece of chromosome. It is made up of a small bit of the gene material called DNA (or RNA). Around this is an outside layer of protein. You might say that a virus particle is a small group of genes in a protein wrapper. Viruses are always parasites in the cells of other living things. When they are not in a host cell they are like dead chemical substances. They can even form into crystals, just like a mineral salt!

When a virus particle happens to come in contact with a host cell it becomes attached to the cell, and the gene material slips inside. The protein is left behind. Only the inside part of the virus enters the host cell. There it acts like genes in the cell. It directs the cell's cytoplasm to produce the proteins and gene materials to make more virus particles. When the cell becomes loaded with these new virus particles, it breaks open, and the new viruses are released. They can then infect other cells.

You see, then, that viruses really possess one important characteristic of life. They reproduce. All other activities must be carried on for them by the host cell. Yet it is the virus which directs the host cell to do this. Are viruses alive? You can decide for yourself what you think about this. It depends upon what you mean by the term "alive." If we call them alive, then viruses should be classified as protists. If not, then they are just chemical substances.

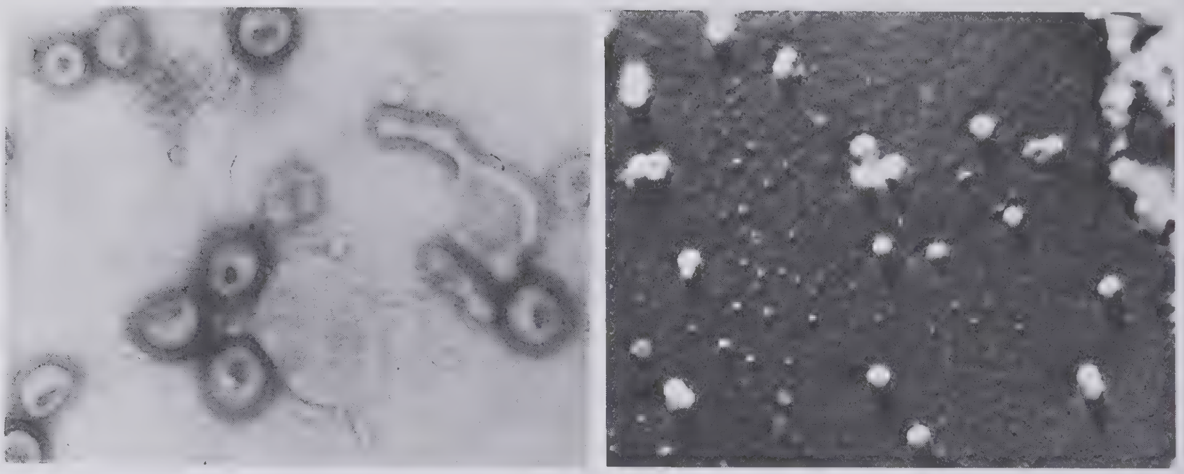


Fig. 20-7. Left: Asian influenza virus; right: common influenza virus. These photographs show the viruses magnified over 150,000 times. Each virus particle is a bit of nucleic acid in a protein cover. (Lederle laboratories; National Institute of Health)

Whatever we call them, viruses are very troublesome to us. They cause a number of serious diseases in man, in plants, and in animals. Even bacteria are attacked by virus parasites. Smallpox, mumps, yellow fever, and the common cold are just a few virus diseases of man.

ACTIVITY

A pond culture. Place one or two handfuls of hay in any convenient dish, pan, or jar. Pour water from a pond, lake, or stream into the jar until it is an inch or two deep. Let it sit for about a week. Bacteria will grow rapidly, using the hay as food. Protozoa already present in the pond water will eat the bacteria and multiply rapidly also. Take drops of water from the surface film of this pond culture and examine them under the microscope. Try to identify the protozoa you see by using reference books. You may also see rotifers. These are small many-celled animals. There may also be some small roundworms and segmented worms. These are described in Chapters 28 and 29. Later, tiny crustaceans may appear.

As you see, a pond culture is a whole community of living things. Keep track of the succession that takes place in it. What is the food supply? What are the first consumers to use this food? What eats them? What changes take place in the protist and animal populations during the next several weeks? Does this community ever become balanced? If so, what are the producers in the balanced (climax) community?

You may wish to try other pond cultures, using leaves, vegetables, or water plants instead of hay. If you do not have pond water use water dipped from any aquarium.

CHECK YOUR FACTS

1. List the four general types of protozoa and describe what each is like.
2. Make drawings of *Ameba, Euglena,* and *Paramecium.* What characteristics are different in each of these three cells?
3. We might call the ciliates and the *Amebas* one-celled animals. Why not call *Euglena* an animal?
4. What are some diseases caused by protozoa?
5. Of what importance are protozoa in the environment?
6. What is a virus?
7. How do viruses reproduce?
8. Do you think viruses are alive? Why?

UNIT 4 SUMMARY

The scientific name of a living thing is made up of two parts: the name of the genus, and the name of the species. Such names are useful because they mean the same thing all over the world. Living things that are closely related have structures that are basically the same. But we still have unsolved problems of borderline types. For instance, there is a question as to whether viruses are living things, or merely active chemical substances.

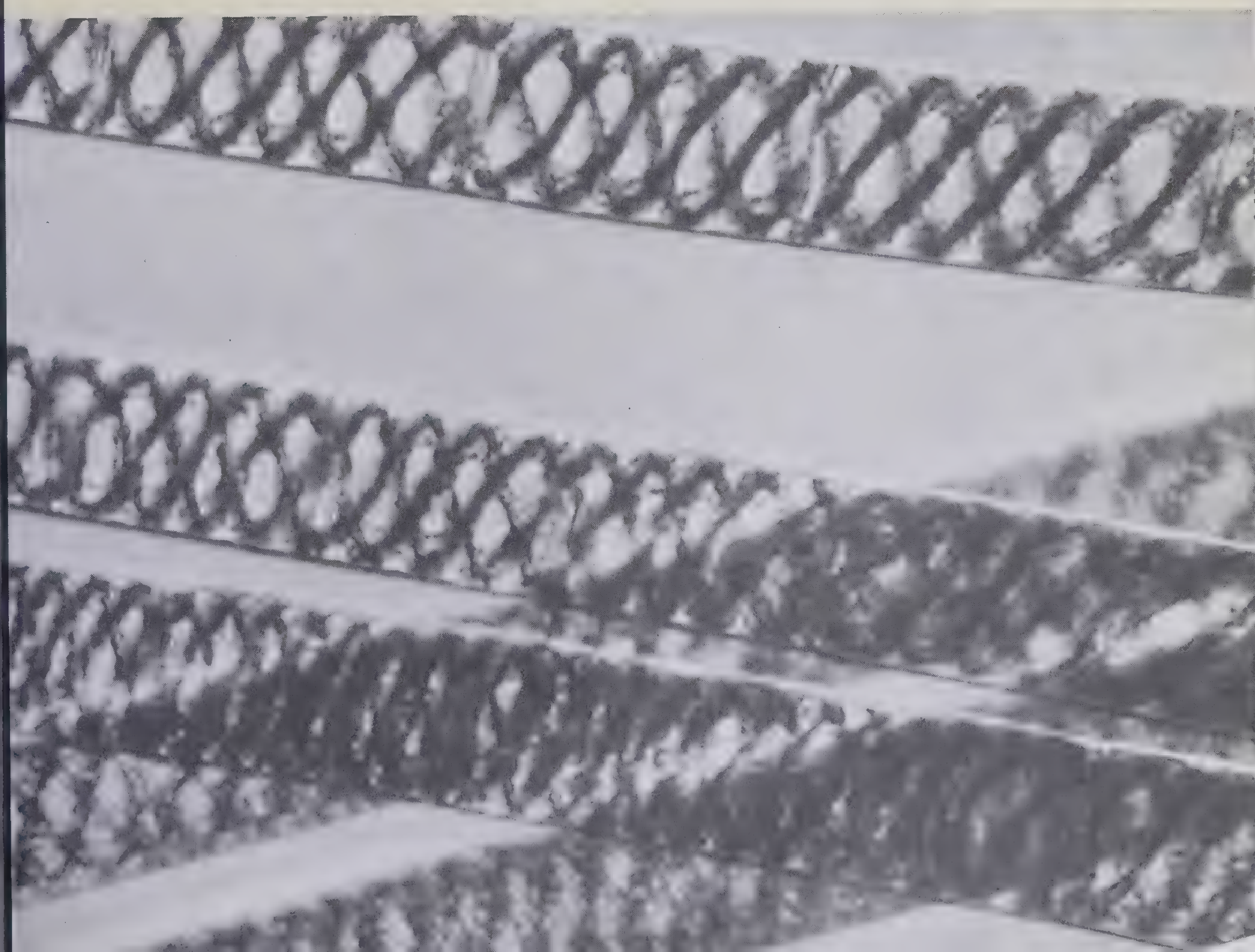
Among the very small and simple living things are the bacteria. They exist all around us, and even on and in our bodies. Most of them are parasites or feed on dead plants and animals. But some of the bacteria can make foods. Certain bacteria are very important in decay and in the nitrogen cycle. Bacteria have many practical uses such as the making of certain foods. Some bacteria cause diseases of plants and animals.

The protozoa are mostly one-celled. Some have limy shells. One group moves by flagella and another by cilia. Some species form spores. Some protozoa form cysts when conditions of life are not favorable. Many protozoa are able to move about in liquids, but one group has no means of movement. All the members of this non-motile spore-forming group are parasites and cause diseases of other living things. Protozoa are an important link in various food chains.

UNIT 5

The Plant Kingdom

By now you can understand how important plants are to animals and to man himself. You have learned how they produce food and you realize that nearly all other life depends on this food. Now it is time we took a closer look at the plant kingdom to see what kinds of plants there are. We ought to see how they are organized and of what parts they are made. This unit will give you a clearer understanding of plants and their use by all other groups of living things.



CHAPTER 21

The Algae

We give the name ***algae*** *(al*-jee*)* [sing. *alga (al*-ga*)*] to several phyla of simple green plants. These plants are food makers. Some of them are one-celled. Others live as filaments of cells. Still others form large, many-celled plants. The algae do not have true roots, stems, or leaves like the higher plants. Most of them live in the water, but some species are found in moist places on land.

The algae are simple in structure. We can call them plants because they are plantlike in their cell structure and in their way of producing food. Certainly they are plants in their effect on other living things in the environment.

Types of algae. Freshwater algae are all rather small. Many are one-celled. *Chlorella*, which you studied in Chapter 4, is a one-celled alga. Many others have cells grouped together in long filaments so that they look like green threads. *Spirogyra*, which you studied in Chapter 7, is of this type. These threadlike forms often grow in such thick masses that they cover the surfaces of ponds. They are then known as green pond scums. Bubbles of oxygen catch in the tangled threads and keep the scum floating. Where do these bubbles come from?

In the sea there are also one-celled and threadlike algae. Besides these, some very large, many-celled algae grow in the sea. Some of them are called ***kelps*** (Fig. 21-1). Many kelps are 150 feet long and have one end attached to the bottom, with long, tough stalks trailing up through the water. Along these stalks there are other flat, strap-shaped parts branching off. These carry on photosynthesis much as leaves do in land plants.

Fig. 21-1. This is a bed of kelps which are quite large algae. These are tough and leathery. (Douglas P. Wilson)

They, do not, however, contain water-carrying vascular tissue.

Since the large algae are usually anchored to the bottom they cannot grow in the deep sea. Light for photosynthesis penetrates only a few hundred feet into the water, so that kelps can grow only in shallow water. There is one type, the *Sargassum* weed, which floats on the surface of the water in the warm, southern Atlantic Ocean. Otherwise, the plants of the open sea are the tiny algae which drift in the upper levels of the water.

Other types of many-celled algae are often found growing all over rocks along the ocean shore. Among them are the common *rockweeds* (Fig. 21-2). They are a foot or two long and very tough. They can withstand the beating of the waves on them when the tide is in. When the tide is out, they lie exposed to sun and wind.

Among the algae are some that are bright green, like grass. Other algae are brown or red. All have chlorophyll but in some it is hidden by other pigments.

The large weed beds that are found in freshwater lakes are not algae. They are flowering plants that have become adapted to life in the water. We call them *pond-weeds*. There are very few flowering plants in the sea. About the only important one is the eelgrass, which grows in shallow water along some coasts. Otherwise, the plants of the sea are algae.

As we have said, algae are mostly water plants. Actually, some of them grow in damp places on land. You may see them as a film of green on wet soil or on the shady side of a tree trunk. These algae cannot be active in dry weather.

Fig. 21-2. Rockweeds growing in the region between low and high tides. Even if you live far from the sea you may see these algae used as packing for seafoods which are shipped to your local markets. (Roche)

Importance of the algae. If algae are the plants of the sea, then how important are they? The sea covers nearly three-fourths of the earth's surface. Algae are the food makers of this vast area. The average square mile of the sea produces as much or more food than the average square mile of land. Since there is so much more sea surface, algae produce much more food than is made by the higher plants. Do you begin to see why algae are important? Many small animals, such as shrimp and their relatives, eat simple algae. Fish eat the shrimp, and larger fish eat the smaller fish. In this way the entire ocean community is fed directly or indirectly by algae.

The uses of algae. The importance of algae is hard for us to realize because we live on land. Yet seafood is used by

man in many places. The food material in the fish, lobsters, oysters, and shrimp which are eaten by so many people was first produced by photosynthesis in the algae of the sea. Countries such as Norway, Japan, and Greece depend very heavily on seafoods to feed their people. They have much sea coast but little farmland, so to them the sea is an important source of food.

Certain algae are eaten directly by people. In the past, a jelly-like material taken from a kelp called Irish moss was used as a desert. Now it is more often dried and added to things like ice cream, cosmetics, and medicines to give them a smooth texture. You have almost surely eaten Irish moss in some food. In Asia certain algae are gathered from the sea and eaten like vegetables. They add needed minerals and vitamins to the diet.

In the future we may use algae like *Chlorella* for food, either for cattle or for man. These one-celled plants can grow very rapidly if they are given the right conditions. Then they can be filtered out of the water and packed into solid cakes. Scientists are studying such new sources of food because the human population is growing so rapidly.

A few years ago scientists believed that algae might possibly be used as food in manned space flights. Unfortunately all the kinds tried tasted much like grass so the idea was given up. When man travels in outer space one of the problems will be in changing the carbon dioxide given off in respiration. Remember that algae use carbon dioxide in photosynthesis and give off oxygen. Therefore, it is not unlikely that algae might be used in space ships to absorb some of man's waste carbon dioxide and to supply some of the needed oxygen. Would any of this be necessary on short trips?

Sometimes a jelly-like substance called *agar (ah-*gar*)* is used in laboratories for growing bacteria and molds. Agar is obtained from algae that live in the sea. It can also be used in various foods, since it is really a gelatin.

Certain algae that live in the sea contain lime. No doubt you have often heard of coral reefs. But did you know that algae often form part of them? Some of the reefs in the mid-Pacific are made mostly of lime that was deposited by algae. People call them coral reefs, but algal reefs would be a better name.

Some troublesome algae. Though the algae are simple plants, you can see that they affect the lives of many other living things. Some of them even become a nuisance to us. They may form growths in reservoirs where cities store their drinking water. Then the algae give the water an unpleasant taste and odor. They may also grow in swimming pools, forming a scum on the surface. When this happens, a chemical called copper sulfate can be added to the water to kill the algae. It is not good to use copper sulfate in lakes or ponds, however, because it poisons fish. Algae may even be a pest in aquariums. Floating types may become so common that the water turns green. Other algae will grow on glass sides of aquariums. When there are enough of them, you can no longer see through the glass. This will not happen if the aquarium is kept in dim light.

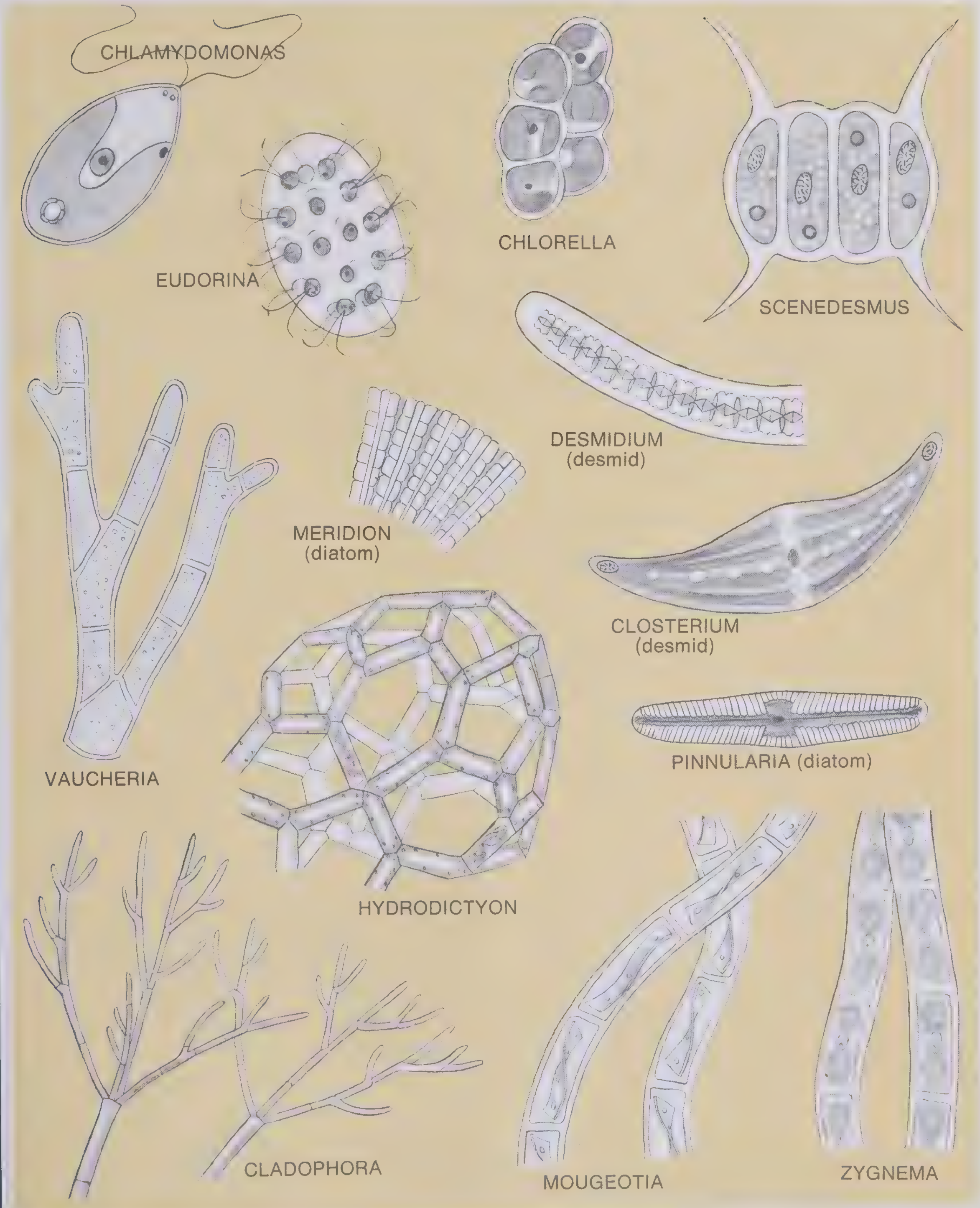


Fig. 21-3. Here are several types of freshwater algae. You need a microscope to study these. Note that some are single cells while others form filaments or chains, or masses of cells.

ACTIVITY

Studying algae. 1. Find some algae and bring samples to school. Look in ponds, lakes, streams, or ditches. Wherever you find green material in the water dip some up and put it in a jar. (Of course the pondweeds are not algae. They are bigger plants with stems, roots, and leaves.) You can even find algae on the shady side of some tree trunks. These algae will look like a thin film of green paint on the tree bark. You may also find algae growing in old aquariums in your school room. If you live near the sea, collect some of the larger algae such as rockweeds and kelp.

Examine the small algae under the microscope. Make a drawing of each kind to record what you see. Examine any large algae which you may have found. Draw them also. Write names under the drawings for all of those which you are able to identify from reference books.

2. Place a handful of green algae under a glass funnel in a jar of water. Over the top of the funnel place a test tube full of water (see Fig. 21-4). Place the entire jar in a sunny window. Watch how gas bubbles rise from the algae and collect in the test tube. What gas do you think this is? Why? Wait until the test tube is full of gas. This will take a few days. Set fire to the end of a long, thin strip of wood. Blow out the flame so that there is just a glowing coal on the end of the wood. Then lift the test tube out of the water and quickly thrust the glowing end of the wood into it. What happens? Your teacher will explain how this is a test for a certain gas. If you do not understand where the gas comes from review Chapter 5.

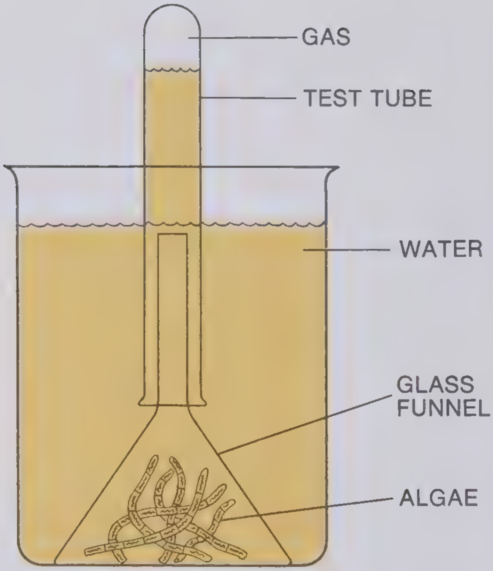


Fig. 21-4. This is an apparatus set up for the experiment to be performed in this Activity.

CHECK YOUR FACTS

1. **How are algae different from land plants?**
2. **Describe some of the freshwater algae.**
3. **What are kelps? Where do they grow?**
4. **What is the general importance of algae?**
5. **In what ways may algae be used by man?**
6. **Why do some algae become pests?**

CHAPTER 22

The Fungi

The ***fungi*** *(fun-*jie*)* sing. fungus *(fun-*gus*)* are an interesting group of simple plants which have no chlorophyll. They include some very simple forms that are sometimes classed as protists. But the fungi you generally see are larger than protists. Some fungi grow in water but many are found on dry land. They include the yeasts, molds, rusts, smuts, and mushrooms. The common toadstools and puffballs that you find around wood lots are types of mushrooms.

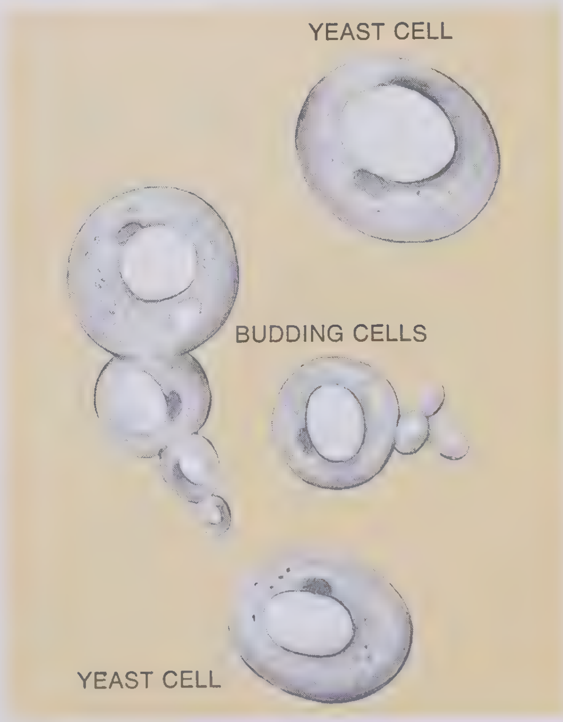
Most fungi are decomposers and cause decay, just as some of the bacteria do. On the other hand, some of them are parasites and get their food entirely from a ***host.***

In getting food, fungi first give off digestive juices to break down the food substances. Then they absorb the dissolved food molecules through their cell membranes. Parasitic fungi cause many diseases of plants and animals such as smut on corn and rust on wheat.

The yeasts. Common ***yeast*** is an example of a one-celled fungus. The cells look like those in Figure 22-1, and they divide in a curious manner called *budding.* First the nucleus divides by mitosis. Then one nucleus moves out against the cell membrane. The wall bulges outward, and the nucleus moves into the bulge. Slowly the bulge, or *bud*, as it is called, grows and becomes a whole new cell. When yeasts are growing rapidly there may be more than one bud on a cell at a time. Also, one bud may appear on another bud. This results in a many-celled appearance, but soon the cells separate and become ordinary one-celled yeast plants again. Yeasts also reproduce by spores.

The main energy food of yeasts is

Fig. 22-1. Cells of ordinary baker's yeast as seen under the microscope. Why are some of the cells bigger than others?



sugar. They can break it down as we do to produce carbon dioxide and water, but if air is lacking they break it down without using oxygen. The products of this process are carbon dioxide and alcohol. In this form of respiration, molecules are changed to release energy without the use of oxygen. It is called ***fermentation.*** In this particular case it is called *alcoholic fermentation.*

Yeast is useful to man both for the carbon dioxide and the alcohol it produces. When a baker makes bread he adds yeast to the dough and puts it in a warm place. Yeast cells carry on respiration, producing carbon dioxide. Because the bread dough is gummy, the carbon dioxide cannot escape. It collects in bubbles, causing the dough to swell up, or "rise." Dough is baked in this puffed-up condition and the result is bread. The alcohol escapes into the air in the oven during the baking process.

The alcohol produced by yeast plants may be used either as industrial alcohol or as beverage alcohol. Alcohol is one of the most important chemicals used in industry, and large amounts of it can be produced by using yeast to ferment molasses. However, much industrial alcohol today is made synthetically without yeast.

Beverage alcohol is made by allowing yeasts to ferment fruit juices to produce wine, or grain products to produce beer. The more concentrated drinks, like whiskey, are produced by distilling fermented grain products.

Fig. 22-2. A close-up view of a bread mold.

Molds. The word ***mold*** is used for any fungus which has a threadlike form of growth. When molds grow on a food material they have a fuzzy appearance. Figure 22-2 shows a common type which grows on bread or any other starchy material. This bread mold develops from spores which drift in the air. If a spore falls on a slice of damp bread, it grows by sending out branching threads. Each thread is surrounded by a cell membrane and cell wall. It contains cytoplasm and many nuclei. These threads grow down into the bread. They produce enzymes which digest the bread. Then the digested material is taken into the thread-like parts of the mold.

Meanwhile, other threads of the mold grow across the surface of the bread. At their ends, a new set of branching threads moves down into the bread, and so the mold spreads.

Some threads grow up into the air.

The ends of these swell up to form little balls. These are the spore cases. Cell division inside these cases produces spores, large numbers of which are carried away by air currents.

The threads of bread mold are white. Its spore cases are black, so the moldy bread has a gray appearance. There are many other molds besides bread mold. Some are green, but not because of chlorophyll. Others are orange, yellow, pink, or black. Some produce their spores in long chains, like strings of beads. Some molds live in the water (Fig. 22-3).

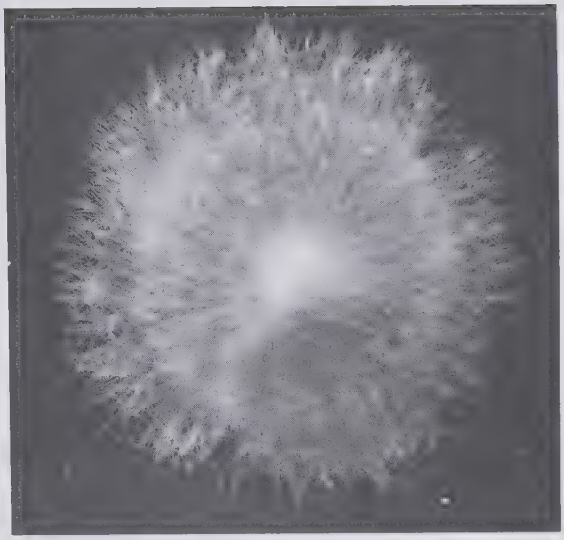


Fig. 22-3. A typical water mold growing on a seed floating in the water. (Courtesy of the Carolina Biological Supply Company)

Importance of molds. In general, we can think of the molds as decay producers, like bacteria. They grow on bread, fruit, cheese, or other human food. They also grow on leather and cloth, and even on damp wood. Things will not mold if they are kept dry. Bakers put a chemical in bread to slow down mold growth, but in time mold appears anyway. As decay producers the molds are less important than the bacteria.

Certain cheeses, such as Roquefort and Camembert, get their special flavor from harmless molds that grow in them. You know what a useful drug penicillin is. It is taken from a green mold, *Penicillium*. This mold produces penicillin which kills the bacteria that compete with it for food. We use it to kill certain parasitic bacteria that have entered our bodies. Penicillin is called an ***antibiotic*** (an-ti-by-*ot*-ik). We now get a number of antibiotics from both molds and bacteria.

Disease-producing fungi. A few kinds of fungi attack man. Some grow in the skin and cause ringworm. One type of ringworm is athlete's foot. If you get a case of athlete's foot you are a little bit moldy! There is a more serious fungus disease that attacks the lungs. It may cause death.

Most parasitic fungi attack plants. Rusts, smuts, and blights are mold-like fungi that grow in or on higher plants. Their threads grow into the tissues of the host plant and use its protoplasm as food. The results can be very serious. The American chestnut used to be an important forest tree in the eastern part of our country. A fungus blight wiped out this valuable lumber species. Now most of our American elm trees are dying from damage done by Dutch elm disease which is also caused by a fungus. It is carried from tree to tree by beetles.

The potato blight in Ireland in the 1840's completely destroyed the valuable potato crop. Many Irish people starved to death, and many others came to America. The potato blight still gives trouble, but now we know

how to protect the plants by spraying them. The leaves are kept covered with chemicals that kill the fungus spore before it spreads. All of our fruit crops are sprayed regularly to prevent both insect and fungus damage.

Another serious fungus disease is wheat rust. It is called a rust because some of the spores are a rust-red color. They break out through the surface of the wheat plants, giving them a rusty look. Plant breeders use artificial selection to produce new types of wheat that will not be damaged by the rust.

The higher fungi. The higher fungi are larger and more complex than the molds. They include the mushrooms, puffballs, and shelf fungi. Some are parasites on living trees, but most of them use dead materials for food. They cause decay of dead leaves and wood in the forests. Forest soils are often too acid for bacteria to grow well, and so the fungi are the main decay producers.

In the rotting leaves on the forest floor the strands of fungus tissue digest and absorb their food. Figure 22-4 shows such a fungus mass. When this fungus plant has grown strong enough its cells multiply and form the ***fruiting body.*** This is the spore-producing organ of the fungus. One fruiting body you are familiar with is the ***mushroom.*** In Chapter 7 we decribed how spores are formed on the underside of the mushroom cap. When the spores have been shed, the fruiting body dies, but the main part of the mushroom plant goes on living. It may send up more fruiting bodies

Fig. 22-4. The main body of a mushroom. This mass of fungus threads normally grows out of sight in the food material. It digests and absorbs food. Later it may produce mushrooms which grow up above the ground and produce spores. (Harold E. Teter)

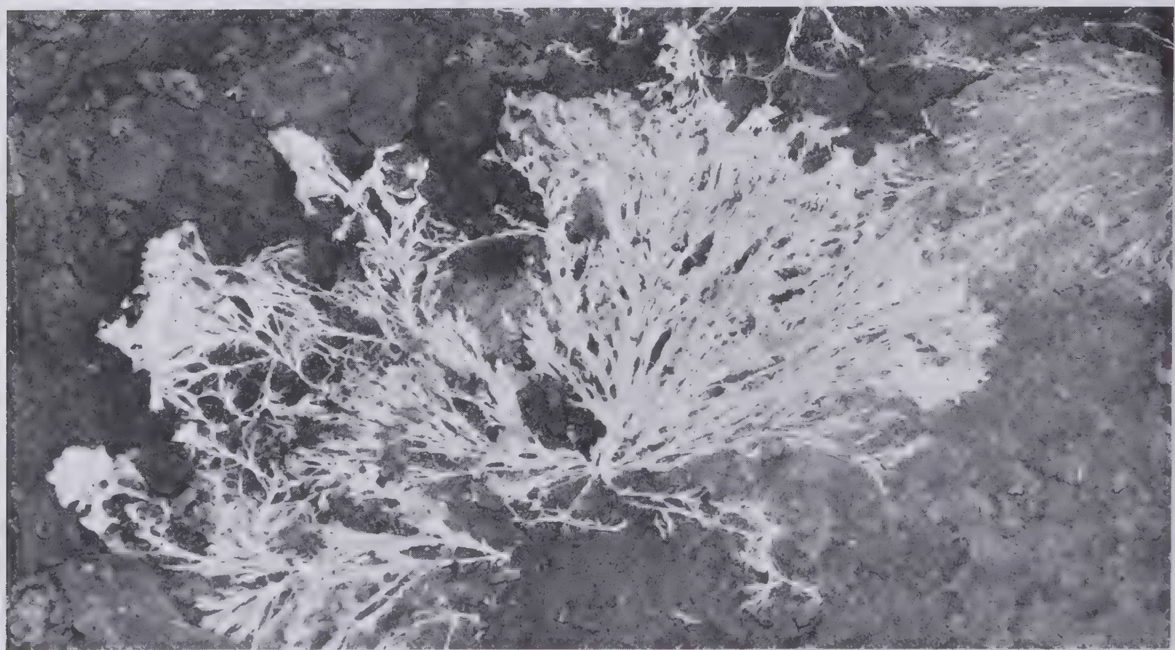


Fig. 22-5. These are shelf fungi growing on a tree in a deep forest. Where is the feeding part of this fungus? (Harold E. Teter)

another year. Often mushrooms appear in the same spot on a lawn each year where some old root or log lies buried. This is the food of the hidden fungus body.

You may have seen fungi which looked like shelves growing on the side of trees or logs. These are the fruiting bodies of the ***shelf fungi*** (Fig. 22-5). They cause decay of wood. If you see one on a tree trunk it may be a parasite, but probably not. The wood in the inner part of a tree is dead. Fungi often rot this inner wood without damaging the living part of the tree around the outside.

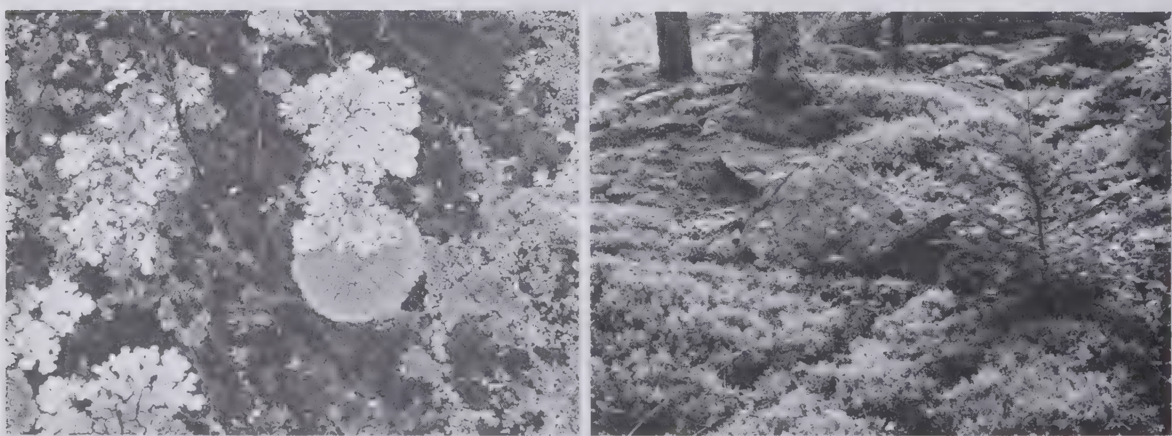
Fig. 22-6. These are some of the many types of spore-producing bodies of fungi. (top to bottom: Harold E. Teter; Harold E. Teter; Gerard / Monkmeyer; Harrison / Monkmeyer)

Fig. 22-7. The death angel mushroom. It looks pretty growing in the woods. It tastes good. But it can kill a whole family! (Walter Dawn)

Puffballs are the globe-shaped fruiting bodies of still other fungi. Some are small, but others may grow as big as your head. They look like very large white marshmallows lying on the grass. When these puffballs ripen, they turn darker and the entire inside becomes filled with spores. If you should happen to kick such a ripe puffball, a cloud of spores would rise into the air like dust.

Fungi that are eaten. The fruiting bodies of some fungi are good to eat. Many people enjoy the flavor of puffballs fried in butter, but mushrooms are the favorites. The mushroom that you can buy in the grocery store is the common field mushroom, but it has been grown in sheds or caves by experts. Some wild mushrooms are good to eat, but others are poisonous. Some of these poisonous mushrooms will merely make you sick, but others can kill. One, the death angel (Fig. 22-7), is so deadly that one mushroom can wipe out a whole family. It is dangerous to eat wild mushrooms because some of the poisonous species look almost exactly like the safe species. Even scientists who were real mushroom experts have made mistakes. They are now dead experts. One mistake is all you can make.

Fig. 22-8. Two kinds of lichens. The one on the left is common on rocks and stones and sometimes on the trunks of trees. The one on the right is "reindeer moss" which is an important food for caribou and musk oxen in the Far North. (George & Sis Bradt; Roche)



The lichens. Out in the country you often see flat, silvery-green growths on tree trunks, posts, or rocks. These are one kind of ***lichen*** (ly-ken). A lichen has such a simple structure you might think that it belongs to one of the algal groups. You would be only half right. A lichen appears to be a single plant, yet it is actually made up of a fungus and an alga growing together. The threads of the fungus give the lichen its shape. The cells of the alga are mixed in among these fungal threads, giving the lichen its green color. The fungus absorbs water from the air. This allows the alga to grow where it could not ordinarily survive. The fungus gets food from the alga. This is an example of very close cooperation between two living things.

Some lichens have a stringy shape and hang down from tree branches. One branching form is about two or three inches high. It covers the ground in many places from southern Canada up through the high tundra in the Far North. Because it is an important food for reindeer and caribou which have no other source of food during the very cold winter months, it is called "reindeer moss."

ACTIVITY

Studying molds. Place a slice of damp bread in a glass dish. Leave it uncovered for several minutes. Then cover the dish with a glass plate (any handy closed container will do). Set the dish aside for several days in a warm, dark place and see if any mold grows on the food. How many kinds do grow? Can you see the center point from which each patch of mold grows outward over the food? How did the mold start at these points? What does this tell us about the air we breathe?

With tweezers pick tufts of each kind of mold and examine them under the microscope. Can you see the spores? Are they produced in the same way by each kind of mold?

Take the mold plants from one patch and rub them lightly back and forth over the entire surface of a slice of damp bread in a dish. Cover the dish and look at it a week later. This time how many types of mold are growing on the food? Explain what has happened?

CHECK YOUR FACTS

1. **What are three industries that use yeast plants? How is the yeast used in each case?**
2. **How does a mold get started in a new location?**
3. **Give an example of a case in which molds are a nuisance. Describe another case in which molds are useful.**
4. **What is the function of the part of a mushroom that you see above ground?**
5. **How do fungi obtain their food?**
6. **Where is the best place to get mushrooms to eat?**
7. **What are lichens? Where do they grow?**

CHAPTER 23

The Mosses

If you have ever walked in the woods you have probably seen moss growing, on fallen logs, and at the bases of trees. You might even find some in your own yard on the shady side of the house. This moss probably looks like a green carpet to you. The next time you find moss, examine it closely. You will discover that it is really made up of a great many little green plants. These little moss plants are usually attached to one another at the base.

The structure of a moss. Figure 23-1 shows one kind of moss plant. As you see, it looks like a small model of the higher land plants. It has structures that look like a stem, roots, and leaves. Actually these structures do not have the highly developed parts of real stems, roots, and leaves. The "leaves" of the moss are just thin sheets of cells—often only a single layer. They do not have any of the complex leaf structure that you will study in Chapter 25.

The rootlike parts of the moss are single rows of cells growing out into the soil. No part of the plant contains any vascular tissue. Water is absorbed by the rootlike cells. It passes from cell to cell up through the stalk to the "leaves," which carry on photosynthesis. Mosses are green and therefore make their own food.

Side branches often develop on the

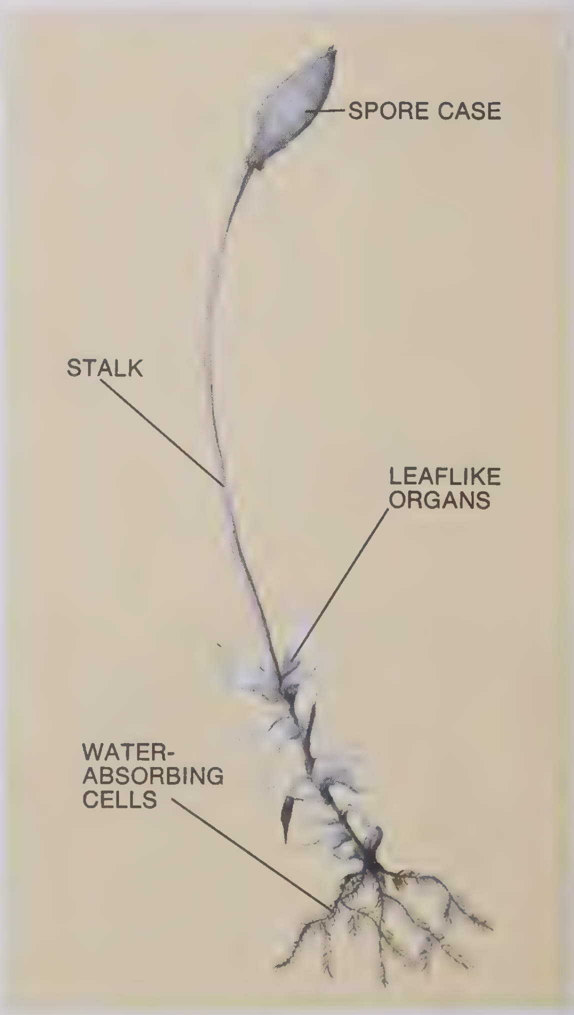


Fig. 23-1. A single moss plant.

Fig. 23-2. A close-up view of a cluster of moss plants. Note the spore cases extended well above the green parts below. (Richard Fischer)

underground parts of a moss plant. At first they are just buds. Then the buds grow and become new moss plants. A new bud grows surprisingly fast. In time, a number of moss plants are joined together by their underground parts. This is how the "carpet" develops.

At certain times a thin bristle develops on the top of the moss plant, above the green part. At its end is a spore case. Spores fall out of this case like salt from a salt shaker. They are carried by the wind and may grow into new moss plants if they land on moist soil. Figure 23-2 shows moss plants with spore cases.

Before spore cases can form, some other things must happen. Sperms and egg cells form at the top of the moss plants. A sperm swims through the dew to reach an egg cell. The sperm unites with the egg cell. Then the fertilized egg cell develops into the bristle and spore case of an adult plant.

Mosses as land plants. You may have noticed that a moss is no more complex than some of the algae. If mosses always grew in the water, we might think of them as one phylum of algae. But mosses grow on land, and only a few are found in fresh water. They are an example of primitive land plant development. Their rootlike structures absorb water from the soil. This is an adaptation to land conditions. Their stalks are strong enough to hold their simple "leaves" up in the light. This again is an adaptation to life on the land.

Mosses are land plants, but they are not very successful land plants. Their water-absorbing cells cannot reach more than half an inch into the ground. If this top layer of soil dries up, the mosses either die or stop growing until it rains again. Their lack of vascular tissue is also a handicap. If a moss should grow a yard tall, the top would dry out in the wind. Without vascular tissue to carry it, water could not rise rapidly enough through the stalk to keep the plant alive. The thin, delicate structure of the "leaves" is also a handicap. They lose water too easily.

As you see, one big problem for land plants, is getting and holding water. The mosses are only partly adapted to the land environment. We shall see in the next few chapters that other land plants are more fully adapted. Most mosses live only in shady, damp locations. Shaded soil is less likely to dry out at the surface than soil in sunny locations.

Importance of mosses. There are a few ways in which mosses affect the communities in which they live. They supply food and shelter for insects and other small animals. They can grow in shade so they sometimes cover the ground on steep slopes in the forest. This protects soil and keeps it from washing away during rainstorms. Mosses also aid in forming the soil. They often grow in shady spots on rocks where there is not enough soil for larger plants. Acids produced by the rootlike parts of the moss slowly soften the rock and break it down into soil. Dead moss parts turn into humus. Finally, there may be enough soil for

Fig. 23-3. Peat moss being baled and ready for shipment. This large peat bog in northern Maine was once a pond which has become filled in by the moss. (Roche)

the larger plants to grow in. What becomes of the mosses, then?

In northern bogs a large type called ***peat moss*** grows so thickly that it is often a dominant plant in the community. This moss contains many hollow spaces which soak up and store water. It is more absorbent than cotton. As the moss grows upward, its lower parts die and pack down into the bog water. This mass of dead moss does not decay very fast because the water is so cold and so acid. It becomes a ***peat deposit.*** Peat is simply a mass of partly rotted plant remains. Peat of this sort is dug up, dried, and used for fuel in northern Europe. We have many peat bogs in the United States and Canada, but we do not use peat for fuel. We have other fuels such as coal and oil which are cheaper and better.

Gardeners mix peat moss into their soils to make them looser and more absorbent. Nurserymen buy peat moss by the carload. They use it to pack around the roots of plants when they ship them. The moss holds water and keeps the roots moist.

Plants related to the mosses. ***Liverworts*** are relatives of the mosses. "Wort" means *plant* in old English. You can find them in damp, low woodlands and along shady stream banks. They often live in places where spray from a waterfall can reach them. Some types grow floating in the water. They are not nearly so common as mosses, and you might live your whole life without ever noticing them, even when they were under your feet!

The plant bodies of most liverworts are flat, ribbon-shaped structures (Fig. 23-4). The ribbon branches every so often as it grows across the surface of the soil. On its underside the liverwort has a large number of rootlike cells growing into the soil to absorb water. But, like the mosses, liverworts have no true roots, stems, or leaves. They are not very well adapted to life on the land.

Fig. 23-4. This is a close-up view of some liverwort plants. The star-shaped organs are the reproductive parts of the plants. (R. H. Noailles)

ACTIVITY

A study of mosses. Bring in a variety of moss plants. Look for them in damp woodlands or anywhere else you might find them growing. Bring in whole layers of the surface soil covered with moss plants. Such a layer looks like a piece of green carpet. Bring similar "carpets" of liverworts, if you can find them.

Examining mosses. Carefully pick single plants from the moss "carpet" and examine them under a good hand lens or a binocular microscope. Are all types of moss alike? If not, how do they differ? Your teacher may ask you to record your observations with drawings. If some of your mosses have spore cases on them crush one on a microscope slide. Make a temporary mount of it and examine it under the microscope. Can you see the spores? Also examine a single moss "leaf" under the microscope. Focus up and down. How many layers of cells come into focus, one after the other? This is a way of seeing how many layers of cells make up the leaf. Do you see any veins?

Growing mosses. The mosses you do not use in this study can be kept alive and growing. Place some woodland soil in the bottom of an empty aquarium. Cover this soil with your moss "carpets." Sink a dish level with the surface of the moss and fill it with water. This will look like a tiny pond. Cover the aquarium with a piece of glass. Keep the moss layer damp, but do not flood it with water. A container like this with land plants in it is called a ***terrarium.*** It makes a nice decoration for the room. It is also a good place to keep small frogs and salamanders (Chapter 34). Individual students can make small terrariums in fruit jars.

CHECK YOUR FACTS

1. **Describe the structures of a moss plant.**
2. **Why do we say that a moss does not have true roots or leaves?**
3. **In what ways is a moss plant adapted to land conditions?**
4. **In what ways does the moss structure handicap it for growing on land?**
5. **How do mosses reproduce?**
6. **Of what importance are mosses?**
7. **What is a liverwort? Where might you find it growing?**

CHAPTER 24

Vascular Plants

The higher plants all have true roots, stems, and leaves. These plant parts contain long cells to carry food and water to every part. Such conducting cells make up ***vascular tissue*** so these plants are called ***vascular plants.*** Most of them live on land and include the *ferns* and their relatives as well as all the *seed plants*. Of these, the seed plants are by far the most important in the modern world.

General structure. You already know that getting and holding water is necessary for the survival of land plants. You have seen how mosses are limited in this respect. The vascular plants have become much better adapted to land conditions. They have roots, which can go deeply into the soil to absorb water and minerals. Most of them have green leaves that make food. These leaves have an outer covering which holds moisture, so they do not dry out too easily. The stems are strong enough to hold the leaves up, so they can receive sunlight.

Water and dissolved food reach all parts of the plant by way of the vascular tissues. The long, hollow cells of these tissues carry liquids much more rapidly than they could travel through ordinary cells. The vascular tissues also give strength to stems. Wood is simply a solid mass of vascular tissue. Its cells have especially thick and tough cell walls.

As you see then, nearly all the things that make the higher plants more complex than the algae are adaptations to land conditions. Any mutations which have fitted them to survive better on land have been preserved through natural selection.

The club mosses. Figure 24-1 shows one example of the ***club mosses***, which are very ancient types. As you see, they look something like big moss plants, and they have clublike structures which give them their name. Some people call them ground pines. But they are neither mosses nor pines. Most club mosses are about six inches high. Several types grow in the northern forests. Sometimes large numbers of these club mosses are gathered for Christmas decorations. Some larger club mosses are found in the tropics and subtropics.

A club moss has simple, scalelike leaves which stay green all year. The "clubs" at the top are really cones and they produce spores. The spores

Fig. 24-1. A cluster of clubmoss plants. These are true land plants with roots, stems, and leaves as well as vascular tissue. Notice, however, that the leaves are stiff and scalelike. (Richard Fischer)

Fig. 24-2. Horsetail plants. Note how the stems are arranged in sections. These are "living fossils" which look today much as their relatives looked over 300 million years ago, although the ancestors were much bigger and taller. (Grant Haist)

are carried by the wind and may produce more club mosses if they fall in a good location.

Horsetails. Figure 24-2 shows another type of vascular plant. It is a member of the group known as the ***horsetails.*** You can tell them by their rough, bushy stems, which look more like a squirrel's tail than a horse's. The stems are in sections which can be pulled apart, and there are little ridges running lengthwise along them. The leaves are small scales and have no chlorophyll. The branching stems are green and carry on photosynthesis. Most horsetails live on moist soil, but some species grow in rather dry, sandy places.

There are also unbranched, reedlike horsetails known as "scouring rushes." Mineral deposits in their stems make them quite rough to the touch. In frontier times they were used for scrubbing kitchen pans.

Ferns. You probably have seen potted ***ferns*** many times. Ferns also grow wild in the woods. They reproduce by spores, just as the club mosses and horsetails do, but in some other ways, they are more highly developed. Their leaves, for instance, are better prepared to make food. Actually, the ferns are more closely related to seed plants than they are to the horsetails and club mosses.

Figure 24-3 shows a typical fern. It

has a creeping, underground stem. From this stem many roots grow down into the soil. From this same stem, large, finely divided leaves grow up into the air. These leaves are often called *fronds*. Water absorbed by the roots passes through vascular tissues to all parts of the fern plant.

Fern leaves have a peculiar way of unrolling at the tips as they grow. The underground stem and the roots live through the winter. In most ferns new leaves develop each year. A fern that you see growing in the woods may be as old as any tree around it.

Importance of ferns. One kind of fern is very common on sandy soils of the United States and Canada. It is called the bracken fern. Wherever northern pine forests have been cut or destroyed by fire, the bracken fern tends to come in. In these cutover areas the new trees that come in first are often a small species of poplar, called aspen. Under the poplars, the bracken grows waist high, covering the ground completely (Fig. 24-4). The yearly rotting of bracken leaves helps to build up the soil for the return of the pines.

In certain parts of the tropics ferns are more common than they are here, and some grow to be as big as trees. A tree fern looks something like a palm tree. It has an upright stem, and a crown of very large leaves at its top.

The seed plants. Ferns, club mosses, and horsetails have one big disadvantage. They reproduce only by means of spores. A spore is so tiny that it takes a long time for one to grow into a very

Fig. 24-3. The photograph shows young ferns pushing their coiled leaves up through the ground. The stems are located under the soil. Spore cases are borne on the leaves and look like black dots, as you can see from the drawings which show several different types of fern leaves. (Lynwood M. Chace)

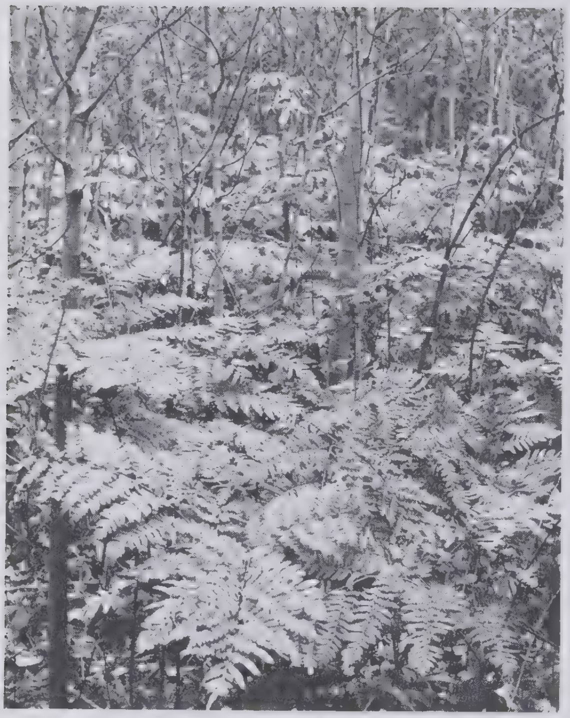


Fig. 24-4. A fine colony of bracken ferns growing under a clump of aspen trees. This is a stage in plant succession which has followed the cutting and burning of white pine lands in the northern forest. (Richard Fischer)

big plant. All during that time it is in danger of drying up. (These groups also have sexual reproduction in which the sperms must swim through rainwater or dew to reach the eggs.)

Seeds are the answer to this problem. A seed is so much bigger than a spore that it has a much better chance of growing. As you already know from reading Chapter 8, the seed contains an embryo and a food supply. By the time this food is used up, the young plant is well established. It needs some moist weather to start growing, but after that, ordinary dry spells will not destroy it.

The presence of a pollen tube that brings the sperm to the egg cell is one of the seed plant's adaptations to land life. This tube prevents the sperm from drying. It makes fertilization possible where no water is present.

There are two main groups of seed plants. These are the ***flowering seed plants*** and the ***nonflowering seed*** plants. The most common examples of nonflowering seed plants are the evergreen trees, which keep their leaves (needles) throughout the year. These include pine, spruce, fir, hemlock, juniper, cedar, cypress, and redwood. These trees have cones instead of flowers. The seeds develop in one kind of cone. The pollen is produced in smaller cones which fall off after the pollen is shed. Pollen is carried by the wind.

The leaves of plants in the pine group are needlelike and look as if they had been varnished. These leaves are able to hold water well. This is one reason why pines so often grow on dry, sandy soils where water must be conserved. In Fig. 24-5 you see leaves of a ginkgo tree. This nonflowering plant is unusual because it has leaves instead of needles. It is frequently planted in public parks and sometimes in backyards.

Flowering plants are the most abundant land plants on the earth. They include our common broad-leaved forest trees, like oaks, maples, beeches, hickories, ashes, and elms. They also include the common small plants like grasses, weeds, flowers, and farm crops. They are the main plants in the tropical rain forests, the broad-leaved temperate forests, the grasslands, and the deserts.

All of our common food plants are in the flowering plant group. The grass family feeds more people than are fed by all other foods put together.

Fig. 24-5. Nonflowering seed plants. Top left: pine leaves and cones (Roche); center left: leaves of the Ginkgo tree (U.S. Forest Service); bottom left: a cycad tree with cone (Julia Morton); top right: a single pine tree (Grant Heilman); bottom right: blue spruce trees (U.S. Forest Service)


Fig. 24-6. The flowers and trees here are typical of the group of flowering plants that have taken over the world in most places. Left: the tiny Phlox and the larger daffodils have attractive flowers (Grant Heilman). Right: the field of grain and the trees and shrubs in the distance all belong to the group of plants known as flowering plants. Their small flowers are not showy and many of them are wind pollinated. (Carl May Seed and Nursery Company)

Rice, wheat, corn, oats, and barley are all grass plants. Without them there would not be as many people on the earth as there are today. All of our vegetables and fruit trees are flowering plants. Even our meat comes indirectly from flowering plants, for the meat animals eat flowering plants such as grasses and others.

Of course there are many other useful products that come from seed plants. These include lumber, rubber, turpentine, clothing fiber, paper pulp, oils, drugs, and dyes.

History of the vascular plants. The first land plants to become really abundant were the spore-producing vascular plants. These formed rich forests on the land over 300 million years ago. They continued to be the main plants, at least on low swampy ground, for about 50 million years. Club mosses grew into large trees over 100 feet high and six feet thick. Tree ferns were common, and even the horsetail group produced tree-sized plants.

The climate was mild in those days, and there was much swampy ground. In these swamps great peat deposits built up. Later the peat hardened and became coal. This period is often called the Coal Age. Figure 24-7 shows how a Coal Age swamp might have looked. There were tree-sized club mosses, large ferns, and horsetails.

There also were some early seed plants—called seed ferns—which looked like ferns but produced seeds. There are no seed ferns left in the world today. The seed plants of today probably evolved from these early seed-bearing types.

It may be that seed plants first developed on dry ground. That is where seeds are most useful. We do not get

many good fossils of dry-land plants. For this reason we cannot say just how things looked on higher ground during the Coal Age.

The Coal Age came to an end about 250 million years ago. At that time, the climate gradually became very cold. There was a long Ice Age more severe than the recent one. The cold climate wiped out the Coal Age forests.

The nonflowering seed plants became dominant in the warmer age that followed. They developed from plants that had survived the cold period. Redwoods were common. There were many ginkgos and many species of a group called *cycads (sykads)*. Only one ginkgo and a few cycad species are left today. This period could be called the Age of the Nonflowering Seed Plants. But it is more often called the Age of Reptiles, for this was the time of the dinosaurs.

Then, about 100 million years ago there came another change. This time it was probably not caused by climate but mainly by competition among species. The flowering plants had appeared on the earth. We do not know just where they came from, but they developed somewhere through natural selection from the nonflowering

Fig. 24-7. A swamp in the Coal Age about 275 or 300 million years ago. The peat which formed in these swamps became the coal we use today. (Buffalo Museum of Science)

plants. The flowering plants have more efficient vascular tissues. Their reproduction is also more efficient. They have been able to crowd out the nonflowering seed plants over most of the earth, but the pine family still holds its ground in certain places.

Incidentally, most of the reptiles died out after the flowering plants took over. The mammals and birds became the common types of animal life.

Scientists have discovered these interesting facts about plant and animal life in the past by observing the various kinds of fossils which tell a story about environments at the time. When rocks yield fossils of the same kind even though the rocks are separated by thousands of miles, scientists know that the same kind of plant or animal must have lived in that locality. The record is still far from complete, but we do learn more and more about life in the past whenever a new fossil happens to be dug up.

From this brief history, you will see that our club mosses, horsetails, and ferns are the last remnants of what were once important groups. Even the nonflowering seed plants continue to lose ground. Today, the flowering plants have taken their place as the most important forms on the land. Meanwhile, the old, primitive algae continue to be the main sea plants.

ACTIVITY

Observing vascular plants. Carefully examine specimens of club mosses, horsetails, ferns, nonflowering seed plants (pine, spruce, etc.), and flowering seed plants. Write a paragraph describing the plants of each group. Do not use information from the book. Base your descriptions upon your own observations. Explain how these plant groups are alike and how they differ from one another. This is the same sort of process the scientists went through when they first studied and named these plant groups.

CHECK YOUR FACTS

1. **Why is vascular tissue very important to land plants? What other important adaptations do the vascular plants have?**
2. **How would you recognize a club moss? Of what importance are club mosses?**
3. **How would you recognize a horsetail?**
4. **How do club mosses, horsetails, and ferns reproduce? How does this handicap them in competing with seed plants?**
5. **What fern is fairly important today in some forest areas? Why is it important?**
6. **Which group of land plants is most important today? How is this group useful to man?**
7. **What were the three main periods in the history of land plants on the earth? What brought the first period to an end? The second?**

CHAPTER

25

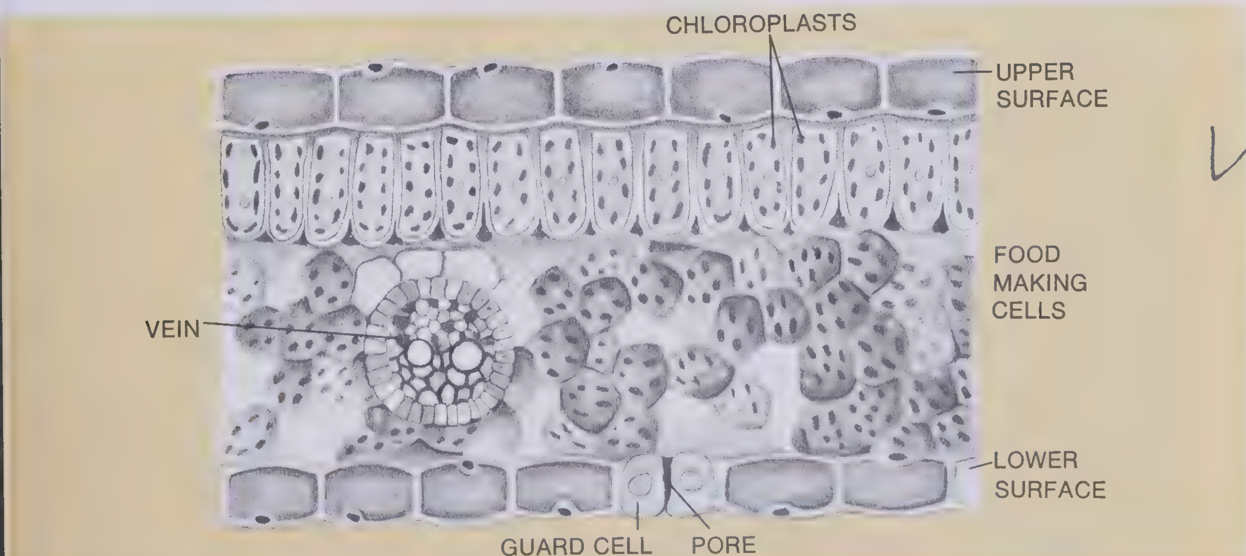
Leaves of Flowering Plants

Since flowering plants are the most common and useful land plants, they are worth some careful study. In Chapter 8 you found out how they reproduce. Now we shall study their leaves and in Chapter 26 their roots and stems.

Leaves are the food-making organs of the plant. Remember that light is the source of energy for photosynthesis. Leaves are thin, and they have flat surfaces. Most of their cells are exposed to the light. The thin shape also allows for good contact with air. Leaves must get their carbon dioxide from the air and give off oxygen into the air. Their veins are made of vascular tissue. They bring water in from the stem, and carry food that the leaf has made to other parts of the plant. Veins also give strength to the leaf.

The structure of a leaf. Figure 25-1 shows how the cut edge or cross section of a leaf might look under a micro-

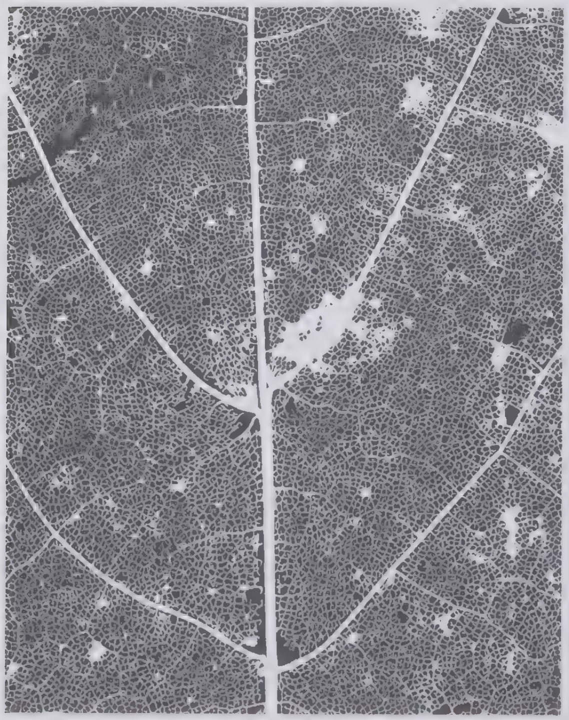
Fig. 25-1. The inner structure of a leaf. Where does the water come in? Where does food leave the leaf? Where does carbon dioxide enter? Where is the chlorophyll?



scope. A surface layer of cells is found on both the top and bottom of the leaf. This surface layer is quite tough and gives strength to the leaf. It often produces a waxy material on the outside. This wax prevents water from evaporating from the leaf. Most cells of the surface layer have no chlorophyll. The light shines through them into the inside of the leaf.

Between the upper and lower layers are the ***food-making cells.*** Notice that they have chloroplasts in them. Cells in the layer along the top surface are long and narrow. Leaves that grow in shady places may have none of these long cells. Near the lower side of the leaf are other cells that have large air spaces between them. These cells are not in the form of layers.

Fig. 25-2. Note the large number of small veins in this leaf. As you can see, no cell in a leaf can be very far from its water supply. (Grant Haist)



The air spaces in the leaf are connected with the outside air so that new supplies of carbon dioxide can enter. The ***pores*** in the lower surface of the leaf, shown in Figure 25-1, allow air to enter. A single leaf has thousands of these tiny pores. In some species they are also present on the upper surfaces of the leaves.

Water enters the leaf through the ***veins.*** In Figure 25-1, a vein is shown in cross section. The cut end of a water pipe looks like a circle. So does the end of this vein. In fact, the vein is like a bundle of small water pipes. It is made up of vascular tissue, and vascular tissue cells are long and hollow, like real water pipes. The upper part of the vein carries water. The lower part is made of the food-carrying kind of vascular tissue. This part carries dissolved food from the leaf to other parts of the plant. Water molecules pass from the vein to the cells lying next to the vein. Then they pass from cell to cell into the rest of the food-making tissue. There are so many small veins in the leaf that these molecules never have to travel very far.

The leaf in action. Now try to imagine the leaf in action. Sunlight shines on the cells. Some of its energy is absorbed by the chloroplasts. The light energy is changed into chemical energy which can be used to carry on the food-making activities of the leaf. The chloroplasts in the food-making cells take water from the veins and carbon dioxide from the air. They rearrange the molecules to form various products including glucose, a simple sugar. Oxygen is given off as a waste product. This oxygen passes into the air spaces and on out through the

pores of a leaf. The glucose, dissolved in water, moves into the veins and is carried to other parts of the plant for use by the cells or it is stored as starch.

The water problem. The food-making cells are moist, and water evaporates from them into the air spaces. This water vapor then passes out through the pores into the air and is lost. Such loss of water is not serious as long as the roots can replace it. But sometimes the ground is too dry, and the roots cannot absorb water rapidly enough. The plant loses water to the air faster than it can get it from the soil. If this goes on very long the plant begins to wilt and then will die.

A leaf, however, can close its pores. This stops the water loss by keeping the water vapor inside the leaf. Carbon dioxide cannot enter through closed pores, so food-making slows down. But this is better than dying for lack of water.

The closing of a pore is brought about by the action of the two *guard cells* that surround it. These guard cells look like kidney beans, and when they come together the pore in the leaf is closed. Figure 25-3 gives a surface view of such a pair. Notice that they are the only cells in the surface layer that have chloroplasts.

When a leaf is drying out, the guard cells become flabby from loss of water. Ridges in their walls act like springs, causing them to straighten out. This closes the pore. When enough water once more reaches the leaf, pressure builds up inside the guard cells, and they are forced back into the curved shape, opening the pore again.

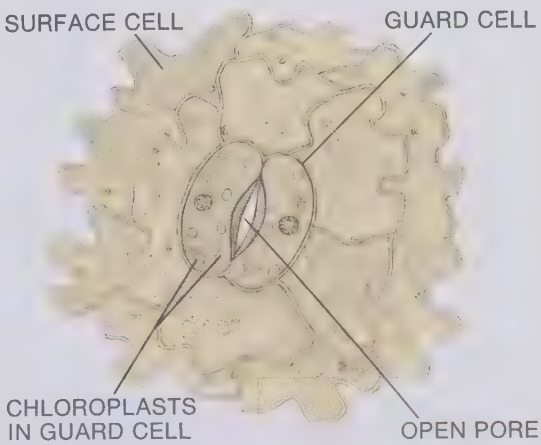
So now you see what the guard cells are guarding against. They prevent the plant from losing too much water. They regulate water loss by opening and closing the pores.

The pores also close at night. This is a good adaptation for land plants, because it helps prevent the drying out of the soil. If the pores did remain open water would evaporate through them all night long. This water would be removed from the soil without doing the plant any good. It would not be there later when it was needed.

The action of the pores is automatic. In darkness the chloroplasts in the guard cells no longer get sunlight. Food-making has stopped. With less sugar in these cells, they hold less water in their protoplasm. They get flabby, and the pores close.

Some desert plants, such as the cactuses, have no regular leaves. Such leaves would lose too much water. The only leaves left on a cactus are modified to form spines. ***Modified*** means changed from the original form. The stems of cactuses are the food-making

Fig. 25-3. Guard cells in a leaf. Notice how they surround the pore. What do these cells guard against?

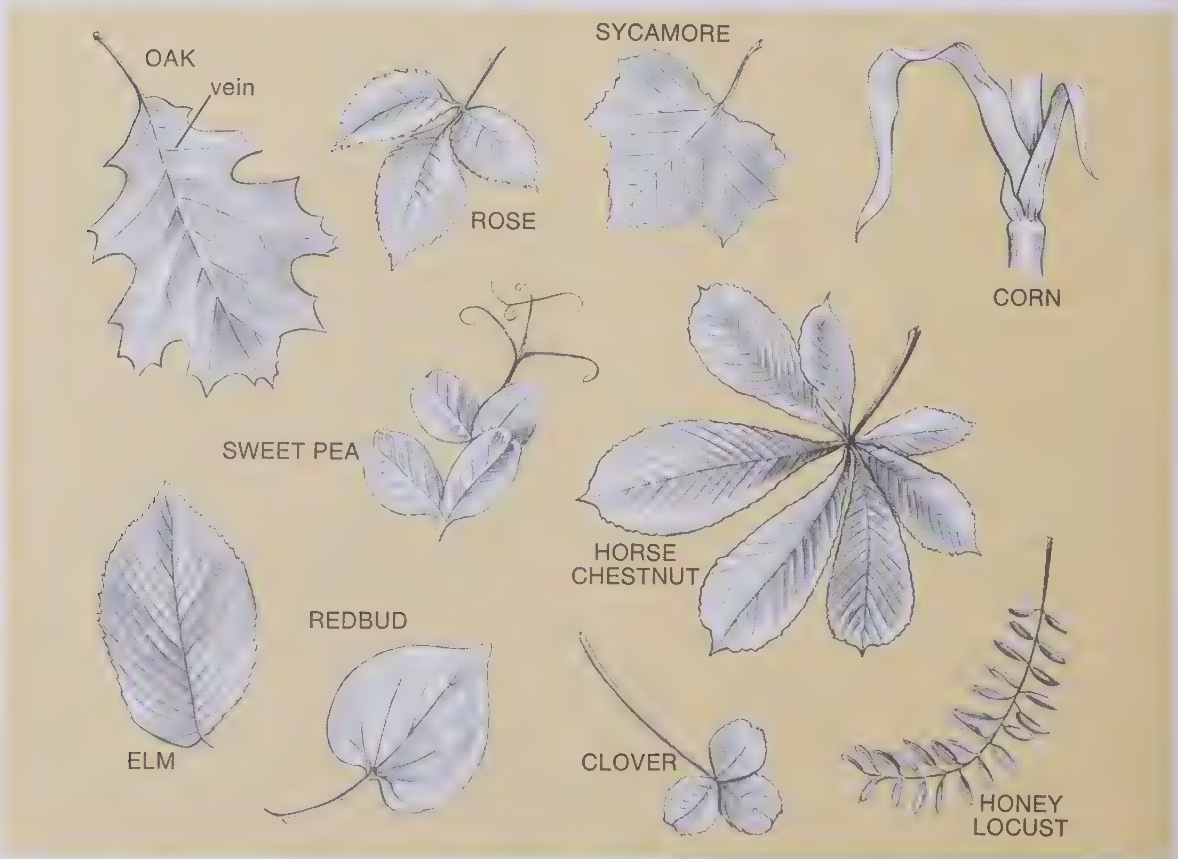


structures and also serve as storage organs for water.

Falling leaves. Some plants grow in warm areas where there is a long, dry season. They may shed their leaves during this dry weather. Winter is a dry season for northern plants. The ground freezes, and the roots cannot absorb ice through their cell membranes. Even cold, unfrozen water is not absorbed easily. Remember how the movement of molecules carries them through cell membranes. At low temperatures, molecules move slowly. With so little water available, leaves would lose too much water even with the pores closed. The shedding of leaves in the fall helps to prevent the drying up of the plant during the winter months.

Leaf coloring. Most leaves are green during the growing season because they contain chlorophyll. But there are other pigments in leaves also. The word ***pigment*** means coloring material. We also speak of pigments in paint. Yellow pigments are always present in leaves, but they do not show in the growing season because they are hidden by the chlorophyll. In the fall, when the temperature becomes too low for chlorophyll forma-

Fig. 25-4. Here are a few of the many different forms of leaves. These differences help us to recognize and identify various kinds of plants.



tion, the old chlorophyll begins to break down. This allows the yellow pigments to show. These yellows account for much of the autumn coloring. The red pigments form in the presence of sunlight. They form from some of the break-down products of chlorophyll. We get our brightest autumn colors in the years with the sunniest fall weather.

Kinds of leaves. Leaves come in many sizes and shapes. In the pines they are needle-like. In the flowering plants they are usually flat and thin. They may be large or small, narrow or wide, long or short. They may have smooth or saw-toothed edges or these edges may be wavey. Some leaves are divided into several leaflets, looking like so many separate small leaves. All of these differences can be used to identify plants. The easiest way to learn the names of trees, for instance, is to look at their leaves and then compare them with the drawings in a tree book.

Looking down on top of a plant you will be impressed with how well its leaves are arranged. They cover the area where they grow completely. Hardly any bare ground shows through the spread of leaves. They catch the light shining on that particular area without much shading of one leaf by another.

ACTIVITY

Observing leaves. 1. Peel a bit of the lower surface from a geranium leaf and study it under the microscope. You know when you have just the surface layer because it is colorless. If any green shows, you have taken too much. Put the leaf part on a blank slide and add a drop of water. Cover it with a cover glass. Now study it under the microscope.

Under the microscope you can see the pores. They look like dark slits. On each side of the slits are the guard cells. They look like pairs of kidney beans linked together at the ends. Or maybe you think they look like a doughnut with the pore in the center. You can recognize the guard cells because they are the only ones in the surface layer containing chloroplasts. You can also see the other cells of the surface layer. Notice how their wavy edges lock together. Notice also the long pointed parts sticking outward from the leaf surface. These are ***leaf hairs.*** They give the under surface of the leaf its fuzzy appearance. Their function is to slow down the wind as it passes over the openings of the pores. This reduces the rate at which water evaporates from the leaf.

2. From your teacher get a prepared slide of some green leaf section. It will show the same sort of view as Figure 25-1. Can you find veins? Are they all sectioned straight across like the one in the drawing? How many layers of long food-making cells can you see? Do you think this leaf grew in sunlight or shade? Notice the air spaces in the leaf. Are there any guard cells? They are hard to see in this kind of section. Remember that the prepared slide does not

show natural colors. The chlorophyll is gone. This slide has been stained with bright colored dyes to make the parts show better.

CHECK YOUR FACTS

1. **Make a drawing which shows the inside structure of a leaf. Label all of the parts.**
2. **Give the function of each of the parts you labeled in item l.**
3. **What advantage is it for a tree to drop its leaves in the fall?**
4. **Why do leaves turn yellow in the fall?**
5. **Why do leaves turn red in the fall?**

CHAPTER 26

Stems and Roots

Most stems have two main functions. They support the leaves of the plant, holding them up in the light. They also carry water up to the leaves from the roots and food down to the roots from the leaves.

Some stems have special uses. As we said in the last chapter, cactus stems store water. Stems may also be modified to store food. A common white potato is an underground stem which stores food and reproduces the plant (Chapter 7). In fact, nearly all stems store some food. Sugar cane stores large amounts of sugar in its stem. This is unusual for many plants store most of their food in the form of starch. Some stems are important as food-making structures. Many stems are especially modified to carry on vegetative reproduction. Some stems bear thorns. Certain vines have small branch stems that are adapted for climbing.

In describing the structure of stems we shall study only the common types, which grow upright and support leaves. Even these take several forms. We shall study three of them.

Structure of stems. Stems must have strength, and they must be able to carry liquids. The carrying of liquids is, of course, the job of the stem's vascular tissue. Most of the strength is supplied by the thick walls of the vascular tissue cells. Other strong types of cells, such as threadlike fiber cells, may help, but the main job is usually done by vascular tissue. Fiber cells are often useful to man. Hemp, jute, and flax are examples of useful fibers.

There are two main types of vascular tissue. One kind carries water and dissolved minerals. The other carries food. Both types are often found together in long strands of tissue passing up through a stem. Such strands are called ***vascular bundles.*** Figures 26-1 and 26-2 show two common ways vascular bundles may be arranged in stems. Now look more closely at Figure 26-2.

The stem on the left has its bundles arranged in a single circle. Tomatoes, cucumbers, buttercups, geraniums, and most common weeds are a few of the plants having this type of arrangement. The stem on the right has its

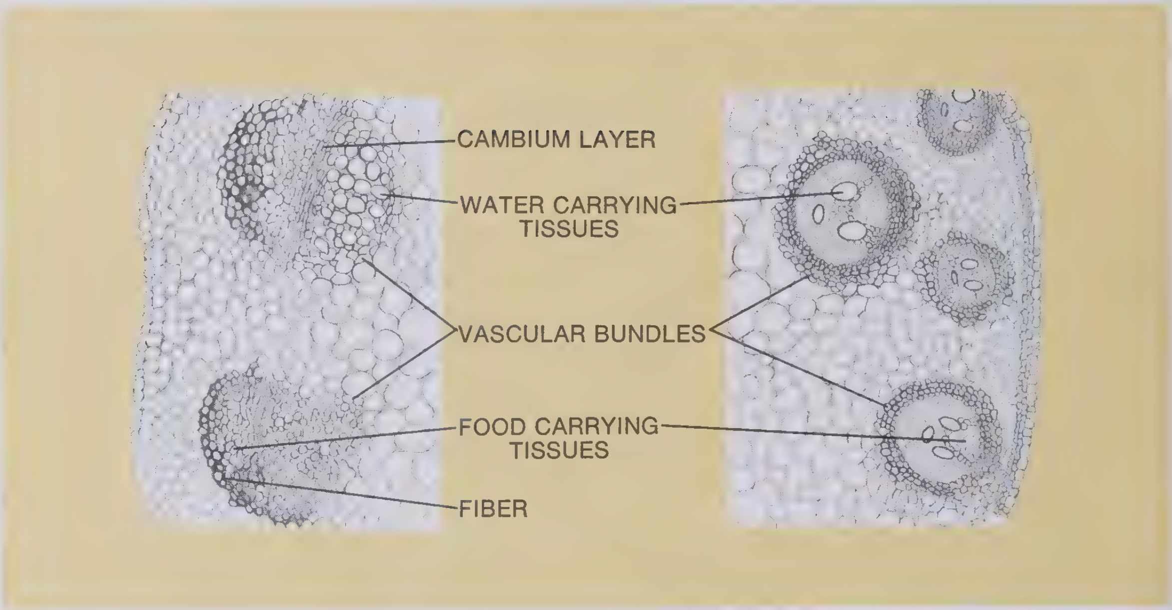


Fig. 26-1. This drawing shows two common arrangements of vascular tissue in stems.

vascular bundles scattered here and there. This arrangement is found in grasses, reeds, lilies, and many other plants. In both types of stems the water-carrying vascular tissue is on the inner side of the bundle, and the food-carrying type is toward the outside.

Woody stems. A third kind of stem can develop from one of the types we have already studied. This is the ***woody stem***—the type that we find in trees and shrubs. Woody stems may live for many years, and they keep growing in thickness. They start out as the form of stem with a single circle of vascular bundles. Such stems have a cambium, or growing layer of cells between the water-carrying and the food-carrying regions.

As you learned in Chapter 7, cambium cells are the growing tissue in stems. Growth in the cambium makes the stem become thicker. All the other cells of the stem become specialized. Some are fiber cells, some surface cells, and some vascular tissue, which contains several kinds of cells. When these specialized cells are fully developed, they can no longer divide.

Only the cambium cells continue to divide. As these cells multiply, some become specialized. Others remain unchanged. These unchanged ones are still cambium cells, that can divide again. The ones that specialize may develop into water-carrying vascular tissue or into food-carrying vascular tissue. The cambium lies between these two kinds of tissue. New water-carrying tissue forms toward the inside of the cambium. Layer after layer is added, and the stem becomes thicker and thicker. Many stems thicken a little bit in this way, and then die at the end of the season. Woody stems do not die. Their cam-

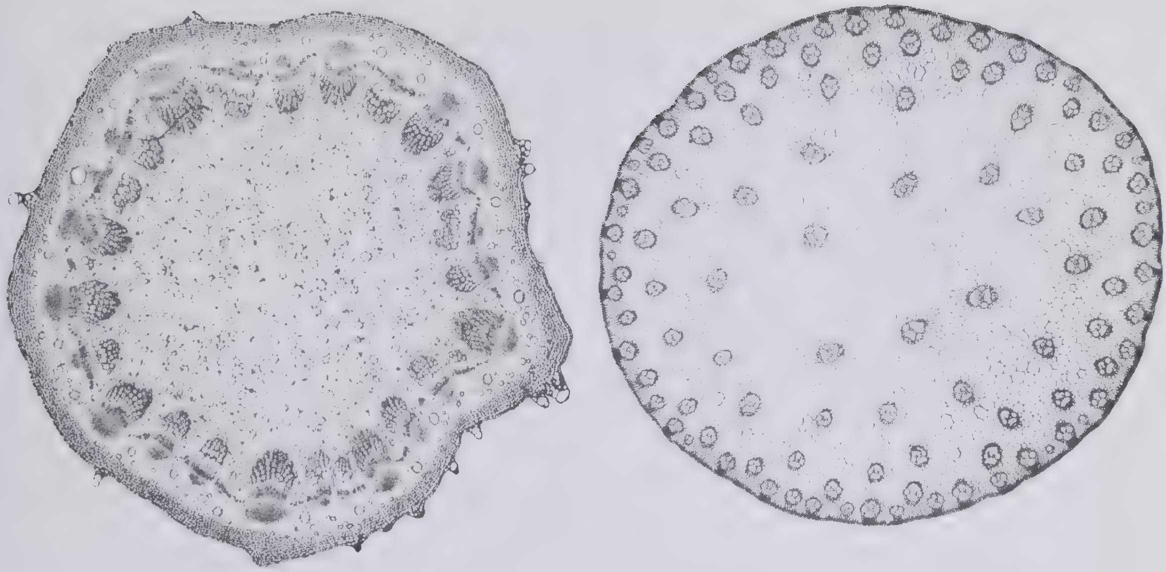


Fig. 26-2. Cross sections of the vascular bundles in a tomato stem (left) and a corn stem (right). These photographs were made by cutting thin slices across the stems. These slices were stained so that the cells would show up and could be photographed under a microscope. Compare these with Fig. 26-1. (Left: William Smith Jr.; right: M. S. Fuller and T. E. Doyle)

bium adds a new layer of water-carrying vascular tissue each year. This is the wood of the tree.

If you look at the cut end of a log you can see the layers of wood. In this view they look like rings, and they are often called ***growth rings.*** You can count them in a log or stump and tell how old the tree was when it was cut.

During the growth process in a woody stem, the cambium itself is pushed outward. The food-carrying cells and the outer layers of the stem are also pushed outward. Many of these outer cells are crushed and die. New cells form and take their place. This outer area of the stem is the ***bark.*** Old bark keeps dying and splitting off, but new bark forms underneath.

Fig. 26-3. The cut end of a log. Notice the growth rings. How are they formed? Where did the water travel in this stem? Where did the food travel? (U.S. Forest Service)

The innermost part of the bark. next to the cambium, contains the food-carrying vascular tissue. So now you can see where materials travel in a tree trunk. Water goes up through the long, hollow cells of the wood. Food moves up or down through the inner bark.

Suppose you were to peel a strip of bark off all the way around a tree. What would happen? Water would still rise through the wood. The leaves would remain green and go right on making food. But food moving down through the inner bark could not reach the roots. In a year or two the roots would use up their stored food. Then they would die. So would the rest of the tree. You see, then, that damage to the bark of a tree can be serious.

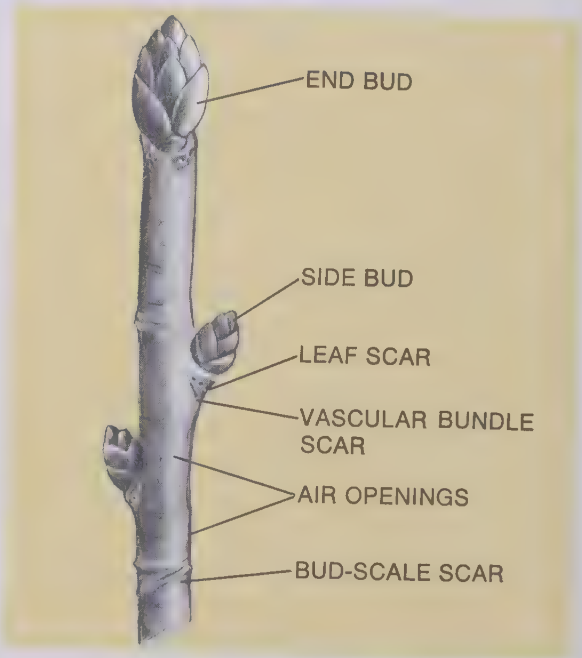
Some trees grow very rapidly. A cottonwood can become four feet thick in 20 years if growing conditions are unusually good. Some other tree may take 500 years to become that thick. You cannot tell the age of a tree by its size alone. Oaks or hemlocks can live a few hundred years. In the West, Douglas fir may live over a thousand years and some redwoods over three thousand. Hemlocks and redwoods are not flowering plants, but their stems grow in the same way. So far as we know, the oldest trees on earth are bristle-cone pines which live in the Sierra Mountains. They are not very big but they live over four thousand years.

In looking at some logs you may notice that the wood in the center is darker than the wood around the edge. This darker wood is dead. All of the living wood is in the outer, light-colored part of the stem. Even there, many cells are dead. Their protoplasm disappears, leaving open channels through which water can rise. Only this outer wood carries water. The dark, center wood is plugged up with gummy waste materials. So you see that although a tree may be very old, its living parts are all fairly young. They may not be as old as a man.

Different kinds of trees form different kinds of wood cells. This is why lumber differs in appearance. You can learn to identify wood by its grain, which is simply the pattern formed by the layers of wood in the growth rings.

Growth in length. Now look at Figure 26-4. It shows a twig, which is, of course, the end of a tree stem. The trunk and all its branches form the stem system of a tree. The drawing shows the twig as it would appear in winter, when no leaves are present.

Fig. 26-4. Outside view of a tree stem, with a bud. What is inside the bud? What comes from the side buds?



On the end and along the sides are the buds. The brown scales covering each bud are really modified leaves. If you should split one of these buds open, you would find that the stem ends in a little point. This stem tip contains thin-walled, simple cells, very much like those in the cambium. This is the growing tip of the stem.

Arranged around the growing tip are small well-formed leaves. They already have stalks and veins and many of their other cells. When spring arrives, cells in the growing tip begin to multiply. The stem begins to lengthen, the bud scales fall off, and the small new leaves grow rapidly. In only a week they reach nearly full size. Most of this rapid leaf growth is a matter of absorbing a great deal of water into the cell vacuoles. If growing conditions remain good, the stem continues to grow in length for as much as a few weeks. Then all growth stops for that year, and new buds begin to form.

Notice that all growth in stem length is at the tip. It is from the bud outward. Older parts, below the bud, never grow in length again. Of course they do grow thicker each year.

Buds on the side of the stem form branches if they grow, but most of them never do grow. They are the stem's reserves. If the end of the stem dies, then the side buds grow out and take its place.

Buds form at the bases of the leaves on a stem. You may not notice them during the summer, because the leaf stalks hide them. The bark of the twig shows scars just below each bud. These scars are the places where the leaves grew. You can even see small dots in the leaf scar where vascular

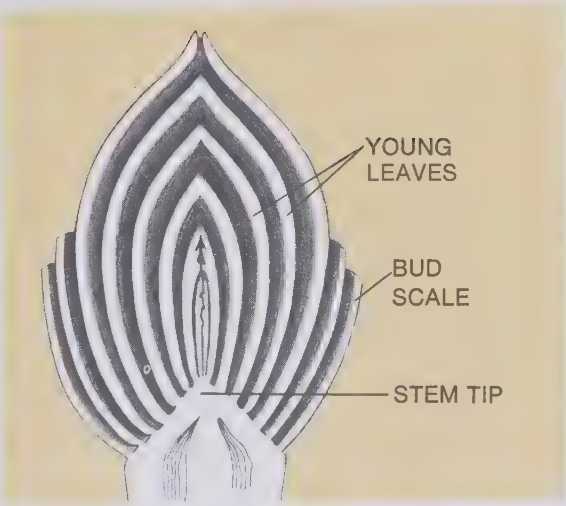


Fig. 26-5. Inside view of a tree bud. How does this structure make it possible for a tree to produce leaves very quickly in the spring?

bundles came through from the stem into the leaf stalk.

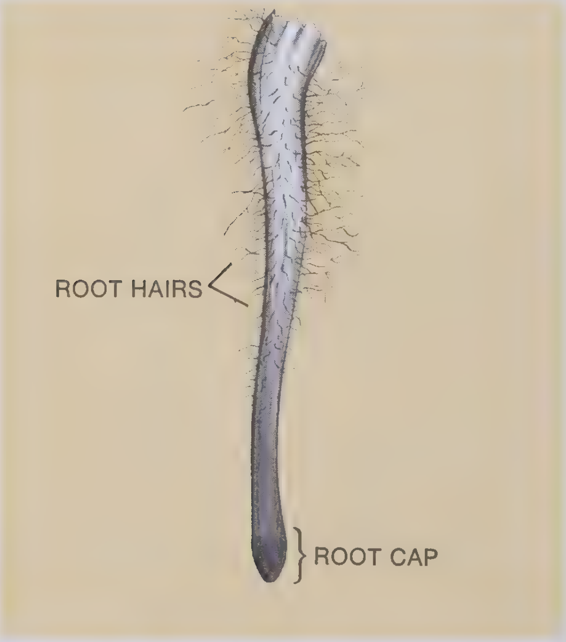
You can also see scars entirely around the twig at certain places. These are where bud scales fell off. They mark the locations of the buds of past years. By measuring the distance between these bud-scale scars you can tell how much the stem grew in length each year. Farther down the stem, the bark is too rough to show these scars.

Over the entire surface of the twig are small rough spots in the bark. These are places where the cells are loose, allowing air to enter the stem. Stem cells are alive, and they need oxygen. They get their oxygen through these small air openings in the bark.

The arrangement and the shape of buds, scars, and air openings is different for each kind of tree. This arrangement helps us identify species in winter, when there are no leaves.

Roots of plants. We have described the three most common types of stems. There are several other kinds of stem structures among the vascular plants, but roots are another story. All roots have about the same functions, whether they grow on club mosses, horsetails, ferns, or seed plants. The main job of roots is to absorb water and dissolved minerals from the soil. Roots also anchor the plant. A large tree with a thick trunk will actually bend in the wind. Imagine what strength its roots must have to hold it against such force.

The big, old roots on a tree look very much like old limbs. They are covered with bark. They have food-carrying vascular tissue in the inner bark. The wood is laid down in growth rings by the cambium, which lies between bark and wood. Of course there are no buds on a root. The eyes of a common white potato are buds. This is one of the ways we can tell that potatoes are not roots, but a special kind of stem.



Old, bark-covered roots do not absorb liquids. The young, delicate branch roots do this job. In this respect roots are something like stems—they must grow each year. Leaves are found only on the new growth of the stem, so the plant must grow some new stem every season. Only young roots can absorb water, so old roots must put on new growth each year.

Growth of roots. All the growth in length of a root takes place at the very tip. Only half an inch back from the tip there is no further growth in length. Of course the root may become thicker. In small, shortlived plants the roots may never grow much in thickness, but in trees they do.

The cells of a root tip grow and divide and repeat this division over and over again. This increase in size develops enough pressure to drive the root tip forward through the soil. You may wonder why these delicate, thin-walled growing cells are not killed as they scrape against the soil particles. They are protected from this danger by the ***root cap.*** The root cap really looks like a cap. It is a layer of cells covering the end of the root (Fig. 26-6). As the root pushes through the ground, the outer cells of this cap are worn off. They are replaced by new cells which form underneath.

Water absorption by roots. The cells which make up the outer surface of a young root are thin-walled and are able to absorb water molecules from the soil. The amount of water that can be absorbed depends upon the amount

Fig. 26-6. A root tip. What does the root cap do? What do the root hairs do?

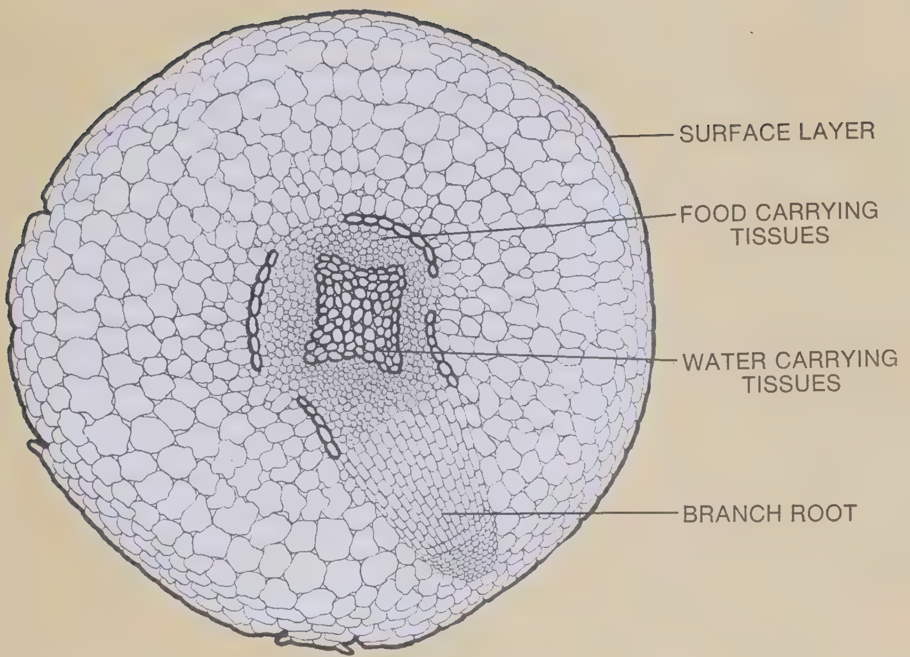


Fig. 26-7. A cross section view of a young root. Notice that there is a root cap on the branch root even before it breaks out through the surface of the root.

of root surface that is exposed to the water. The surface area of the root is greatly increased by the growth of structures called ***root hairs.***

A root hair is a long, slender part that extends out from a cell (Fig. 26-8). It is very well suited for absorbing water. Remember that water molecules are always in motion. They bounce against the cell membrane which covers the root hair. Some of these water molecules pass in through tiny pores in the membrane. These water molecules pass in the same way from cell to cell towards the center of the root and finally enter the vascular tissue.

The center of a young root contains vascular tissue, as you can see in Figure 26-7. New branch roots always start to grow from this central region. They grow out through the outer layers of the root. Water and minerals pass up through the vascular tissue of the root and stem and into the leaves. Food from the leaves moves downward through the vascular tissue to feed cells in the stem and roots. Some of the food may be stored in root or stem cells to be used at a later time.

Remember the description of soil water in Chapter 15. Water that is absorbed by roots comes from the

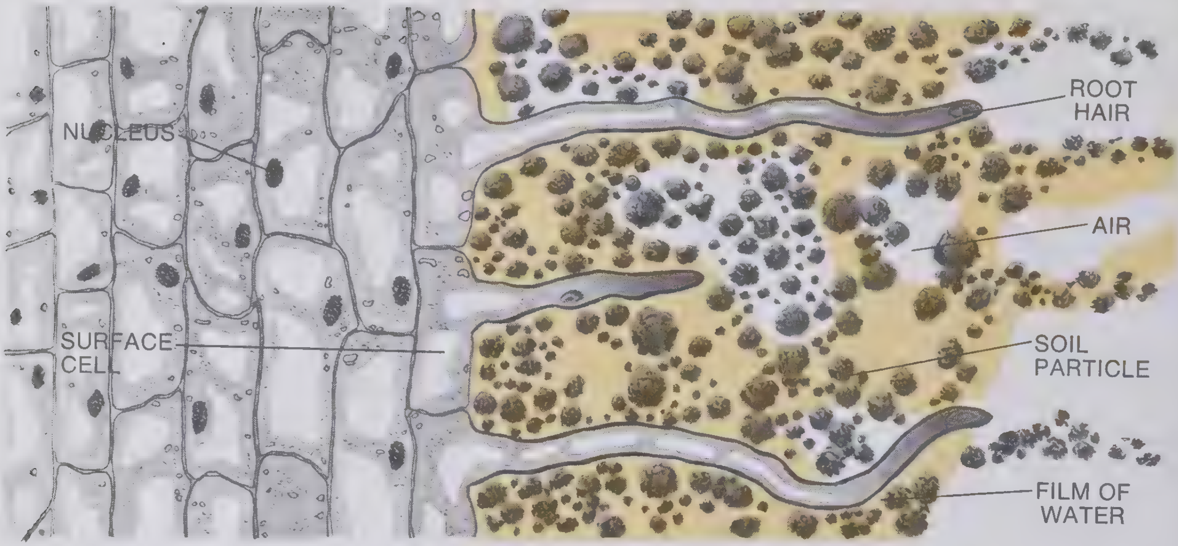


Fig. 26-8. Root hairs in the soil. See how much more area they add to the surface of the root. Why is the amount of surface important?

damp soil that lies above the water table.

Roots are made up of living cells. These cells need oxygen. If the roots of an ordinary land plant were to grow into the ground water below the water table, they would not get enough oxygen.

Study Figure 26-8 carefully. It shows soil particles in black. The water film which clings to the surface of each soil particle is in color. Air is shown in white. See how the root hairs grow in among the soil particles and make close contact with the water film.

Since root hairs are so small and delicate, they do not last very long. This is why the plant must grow some new roots each year—to produce new root hairs. Root hairs are surprisingly efficient. They continue to get water from soil that feels quite dry to the touch.

Types of root systems. The root systems of different plants have a variety of forms. Some plants have many roots that are all about the same size. Grasses are an example of this type. Others have one main root growing straight down into the soil. All roots branching from it are much smaller. Burdock and dandelion have roots of this type. Some roots are thick and fleshy. These are modified for food storage. The carrot, radish, and turnip are roots of this type.

In general, plants adapted to high ground with dry soil have a root system that goes down deep. In these locations the water table is deep also. If roots go far down, they reach damp soil near the water table. Oak and hickory have deep root systems. They are usually found growing on dry soil. Alfalfa is a plant in the pea family. It is about knee high and is often used for hay. In dry country this plant may send its roots 30 feet into the ground.

On low ground the water table is often very near the surface. During a wet spring it may even be above the

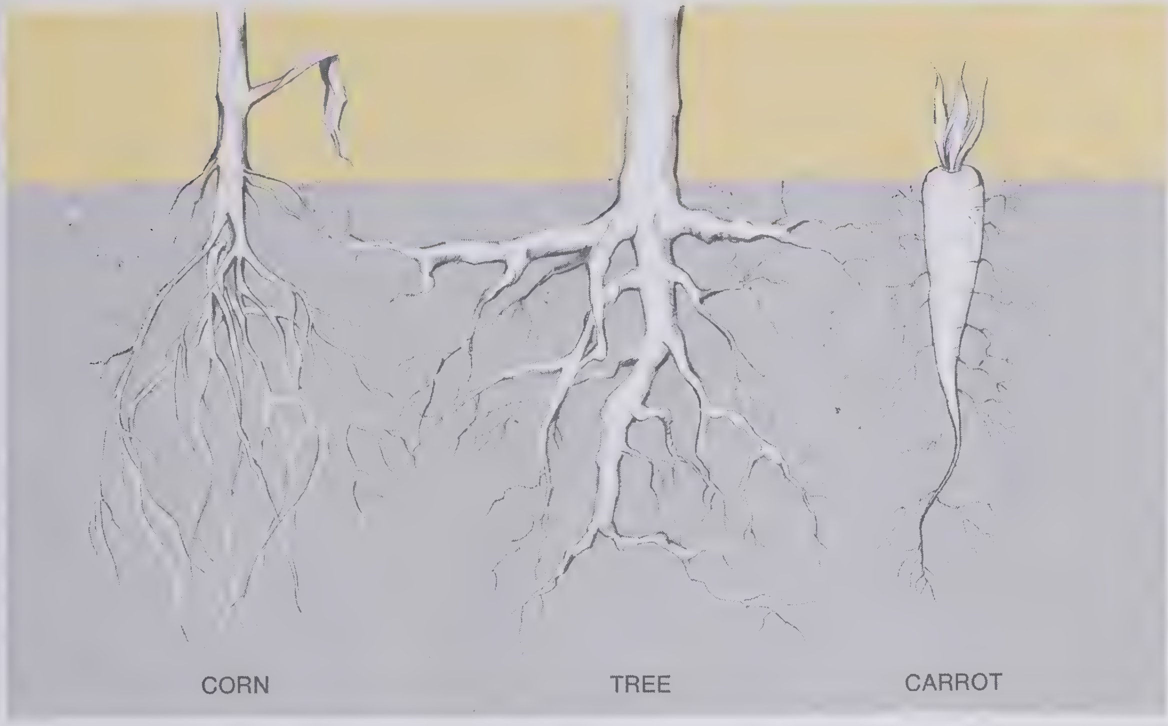


Fig. 26-9. Three different kinds of root systems. Each type is adapted to some particular kind of location. To what sort of locations are each of these three root systems adapted?

Fig. 26-10. Note how much more deeply the hickory roots go into the ground. Why do roots stay above the water table?

surface. In other words, the ground becomes flooded. Plants adapted to these locations have shallow, spreading root systems. If you have ever walked through a lowland forest you have probably stumbled over tree roots lying at the surface of the ground. Here they can obtain oxygen. These roots must be able to live on very little oxygen during periods of flood. Red maple, gum and elm are trees that grow well in such places.

In many deserts there is no water table anywhere near the surface. Rain falls, and the water evaporates without soaking very far into the soil. Cactus plants are adapted to this situation by having a shallow, widely spreading root system. They soak up water when it is available and store it in their stems. Then they live on this stored water for weeks or months until there is more rainfall.

Absorption of minerals. You learned in Chapter 5 that many elements a plant needs must come from the soil.

These elements come in the form of compounds that we call *mineral salts*. Land plants get these minerals from the ground. Soluble mineral salts enter the root hairs in the same way that water does. However, mineral absorption is quite independent of water absorption. Minerals are released slowly from rock particles in soil. The breakdown of rock particles is most rapid near the surface, where weather acts upon them, so most roots grow in the topsoil. Roots that go deeper are used more for water absorption than mineral absorption.

ACTIVITY

Observing stems and roots. 1. Study prepared microscope slides showing cross section views of the three types of stems discussed in this chapter. Locate the water-carrying and the food-carrying vascular tissues.

Study slides showing long sections of onion root tips. You already saw these slides when you studied chromosomes. This time look at the root cap formation at the end of the root.

2. Soak radish seeds in water for a few hours and then place them on some layers of wet paper toweling in a closed petri dish. After a few days they will begin to sprout. Study the roots under a hand lens or a binocular microscope. Notice the fuzzy appearance of these roots. What is this fuzz? What does it do for the plant?

CHECK YOUR FACTS

1. **What are the main functions of stems?**
2. **Vascular tissue is sometimes called the "plumbing system" of the plant. Can you explain why?**
3. **What are the two types of vascular tissue?**
4. **Describe the three main types of stems. You may use drawings as part of your explanation.**

5. What part of a tree trunk carries water to the leaves?
6. What part of a tree trunk carries food to the roots?
7. How can you discover the age of a tree? Would you wish to use this method on a shade tree in your yard? Explain.
8. Suppose your grandfather claimed to be older than the oldest redwood tree. Is there any way in which this could be called a true statement? Explain.
9. What do tree buds contain?
10. In what part of a stem does growth in length take place? Growth in thickness?
11. Explain the markings on the bark of a twig.
12. What are the main functions of roots?
13. What part of a root grows in length?
14. What is a root cap? What is its function?
15. What are root hairs? What is their function?
16. Why do roots stay above the water table when there is so much more water available below the water table?

UNIT 5 SUMMARY

Algae are simple, food-making plants. Most of them live in the sea or in fresh water. Some types are found in damp places on the land. Many algae are one-celled, but others grow as filaments, and many-celled plants like the rockweeds. Algae are the most important food makers of the sea and of fresh waters.

Fungi are simple plants without chlorophyll. Some of them are one-celled and others are many-celled. Among them are the yeasts, rusts, smuts, molds, mildews, and mushrooms. Some fungi are parasites that cause diseases of plants and animals. Others are decomposers that cause the decay of dead materials. We get antibiotics from some of the molds.

The mosses and their relatives are simple, green plants that are able to live in moist places on the land. They do not have true roots, stems, or leaves. Mosses play a part in soil formation. The peat mosses produce peat, which is used as a fuel and as a packing material. Liverworts, which are related to the mosses, live in the water, or in moist places on the land.

Ferns, club mosses, horsetails, and seed plants have vascular tissues. They have roots that absorb water and minerals from the soil. Water and foods are carried to all parts of the plants by the vascular tissues. Club mosses, horsetails and ferns formed vast swamp forests millions of years ago. Much of our coal supply comes from the remains of these early land plants.

There are two large groups of seed plants. The nonflowering seed plants include such evergreen trees as pines, firs, and spruces. The other group is made up of the flowering plants. All of our common food plants are flowering plants.

Leaves are the food-making organs of most of the seed plants. Chlorophyll is not the only colored material in leaves. They also contain yellow pigments. Red pigments sometimes develop in the fall. The yellow and red pigments produce the bright colors of autumn leaves.

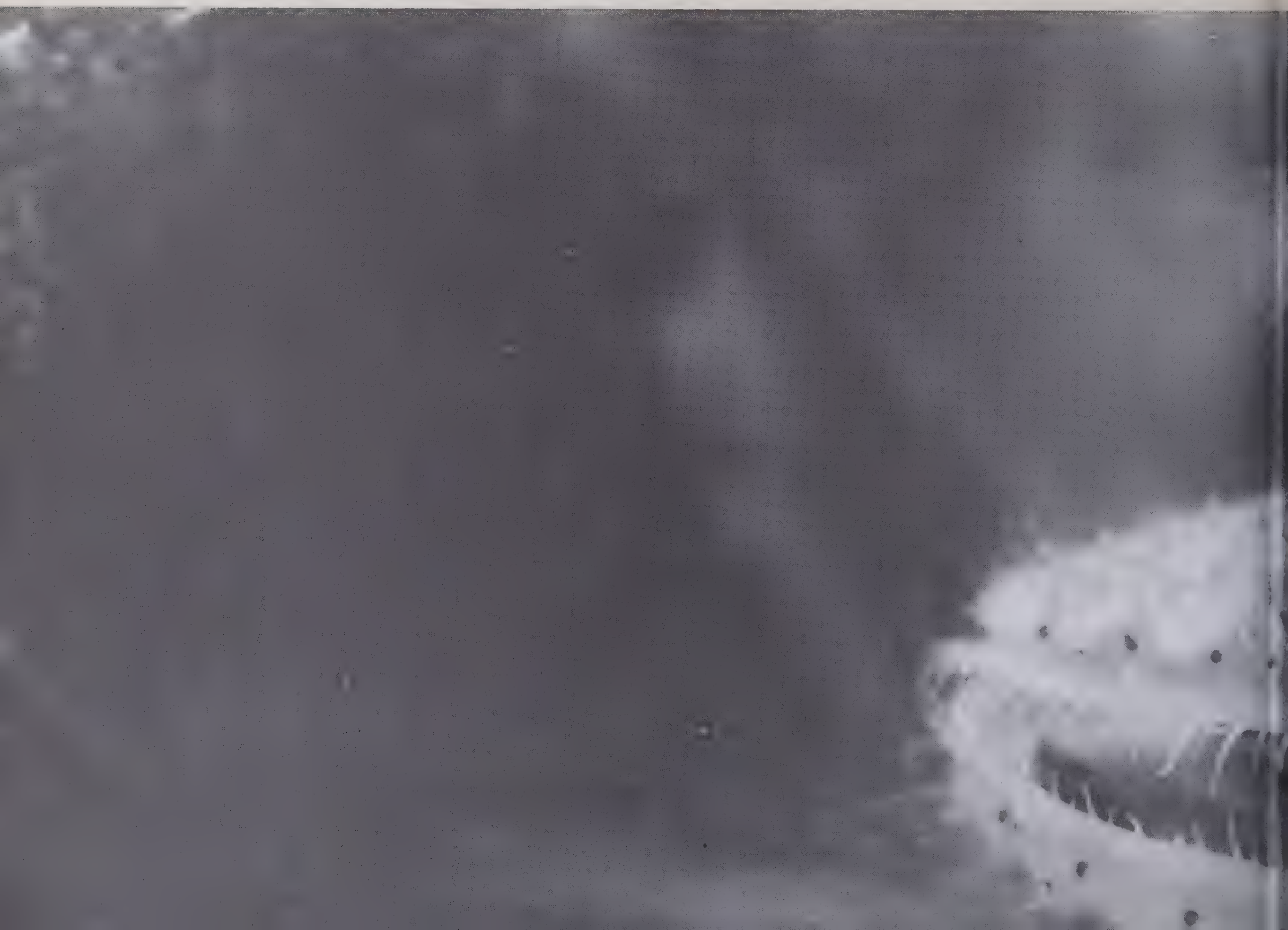
The stems of flowering plants hold the leaves up in the sunlight. They also carry liquids to and from the roots. In some plants stems are storage places for food and water. Food and water pass through vascular bundles in a stem. In one group of flowering plants these vascular bundles are scattered through the stems. In another group of plants the vascular bundles form a sort of ring near the outside of the stem. Stems that have vascular bundles in rings sometimes grow thicker year by year. These are the woody stems. New layers of wood are added each year. Water travels through the wood, and food travels through the inner bark.

Roots anchor flowering plants to the soil. They absorb water and dissolved minerals through their root hairs. In many plants they store food. Some flowering plants have small, branching roots.

Others have one or more large roots bearing small branches. Some root systems go deep into the soil. Others spread out near the surface. The vascular bundles of roots connect with the vascular bundles of stems. There is a continuous path that liquids follow in going from roots to leaves.

UNIT
6

The Animal Kingdom



There are a great many species of animals in our world. Some of them have a simple structure while others are quite complex. You can see how a jellyfish, a tapeworm, a grasshopper, and a man are quite different from one another. Yet all of them belong to the Animal Kingdom.

You probably have a great deal of interest in animals already. In this unit you will study the nine most important phyla of animals. This study will give you a better understanding of the many types of animals, what they are like, and how they affect one another.

Williams National Park Service

CHAPTER

27

Sponges and Coelenterates

Many of the protozoa are animal-like in their behavior. These are often called one-celled animals. Some of them live in colonies. By this we mean that a group of their cells live together in a ball or cluster. Could we call this a many-celled animal? We do not do so because each cell in the colony does everything for itself. In a more complex plant or animal different cells do different things. You have already seen how this takes place in plants. The simplest animals that can be called many-celled are the sponges.

The sponges. You may be surprised to learn that ***sponges*** are animals. For many years they were thought to be plants. They grow attached to some object in the water and cannot move from place to place. They certainly look like nongreen plants more than they look like animals. You will understand sponges better if you study a simple one first. Figure 27-1 shows such a simple sponge. It is about half an inch high, and it is hollow like a small vase. The top is open. The base is attached to a rock, or some other support. A closer look shows that there are many pores opening through the wall of the sponge, making it a leaky vase.

If you dropped a little ink in the water next to this simple sponge, you would find that it is pumping water. The inky water would go in through the pores and out through the top opening. The water the sponge takes in through its pores brings oxygen and food into its body.

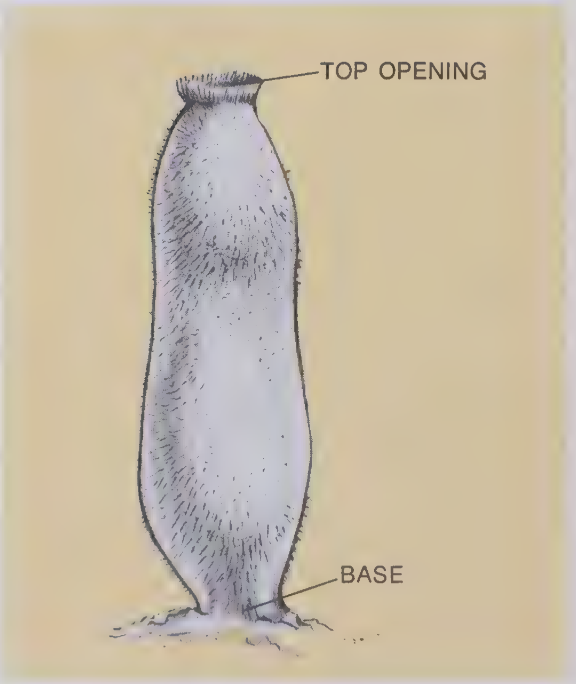


Fig. 27-1. A simple sponge.

Different kinds of cells. Figure 27-2 shows a simple sponge with the upper part cut away to show its structure. Notice the outside layer of ***covering cells.*** The pores of the sponge are formed by ***pore cells.*** The pore is a passage through the middle of the pore cell, like a hole in a doughnut. The pore cells are long enough to reach from the outside to the inside, hollow part of the sponge. The cells which line the hollow space are ***feeding cells.*** Feeding cells have flagella which whip water up through the hollow cavity and out through the top opening. This is how the sponge pumps water.

The feeding cells take in food much as one-celled types do. Bits of food are taken directly into the individual cells and digested. The food used by the sponge is any living or dead material which may be drifting in the water. This would include tiny one-celled algae, small protozoa, or decaying bits of dead plants and animals. There are animals in many different phyla which also obtain their food by straining the water. This is called ***filter feeding.*** Filter feeders are especially common in the sea. Sponges are the first of several which we will mention in this book.

Notice that there is another kind of cell, between the covering layer and the feeding cells, that looks something like *Ameba*. This type of cell moves around in the same way that *Ameba* does. It takes digested food from the feeding cells and carries it around to other cells of the sponge. Sponges have still another type of cell which forms little spiny structures that make up their skeletons. The skeleton is in the body wall, and it is strong enough to hold the sponge upright in the water.

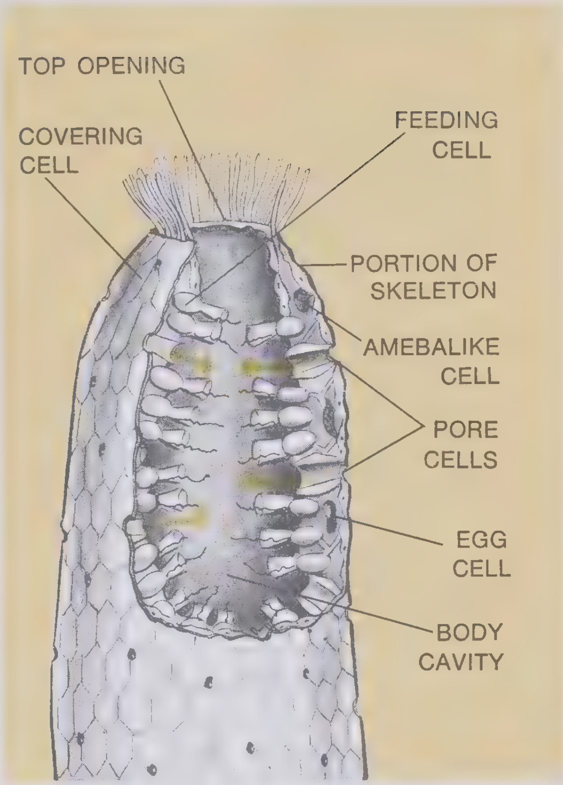


Fig. 27-2. A cutaway view of a simple sponge. Note that the feeding cells have flagella which force water through the body cavity. The water passes out through the top opening.

How sponges reproduce. One way sponges reproduce is by means of sperms and egg cells. The fertilized egg cell develops into a swimming ***larva*** [plur. *larvae* (*lar*-vee)]. The word larva refers to any young animal which is very different from the adult. A caterpillar is the larva of a butterfly. A tadpole is the larva of a frog. The sponge larva is a little saucer-shaped mass of cells covered with flagella on one side. It swims around for a while and then settles down on some solid support. There it grows into an adult sponge.

A sponge may also reproduce asexually by developing a bud near its base. The bud forms an opening at the top as it grows. This explains why you often find whole masses of sponges growing together. In some types the buds do not separate from the parent sponge.

Types of sponges. Besides the simple little sponge that we have described, there are many others. Some of them are as big as your head, and some are bigger. They may be black, red, orange, yellow, blue, or purple. These large sponges have the same kinds of cells as the simple sponge, but they are built up into big masses of tissue. There are passages throughout this mass of cells. These passages connect with many small, hollow spaces, each lined with feeding cells.

The larger sponges live in warm parts of the ocean. Many smaller ones also live there and in colder waters. A few even live in fresh water. The freshwater sponges look like a rough coating all over the outside of a sunken stick or rock. Some are green because of algae which grow in among the sponge cells.

The skeletons of sponges may be made of a large number of simple, three-pointed spines, or they may be more complicated. Some sponge skeletons are made of lime. Some are of a stiff glasslike mineral. Still other sponges have a framework of a softer quite flexible material. The sponges which are useful to man all have soft skeletons. In fact, the skeleton is the part that we use.

Commercial sponges are used for cleaning. Useful sponges may grow in shallow water just beyond the low tide mark. They can be gathered by wading, or by using hooks on the ends of long poles. Others, in deeper water, are collected by divers. Some are found at depths of over 100 feet. Many sponges are found off the coast of Florida. The West Indies and the Mediterranean also produce commercial sponges.

After live sponges are gathered, they are left in the air for several days while the cells die. Then they are cleaned and trimmed. People buy sponges for cleaning purposes because sponges hold water so well.

Division of labor. A cell such as *Chlorella* or *Paramecium* does everything

Fig. 27-3. Sponge fishermen. Cleaned sponges are hanging up just above the men. Newly caught sponges lie on the deck awaiting cleaning. (Higgins/ U.S. Fish and Wildlife Service)

for itself. It gets its own food and oxygen. It gets rid of its own wastes. The many-celled plants and animals produce several different kinds of cells, each with its own job to do. The work of the body is divided up among the different cells. We call this ***division of labor.***

The sponge is a simple example of division of labor. It has seven kinds of cells. There are covering cells, feeding cells, pore cells, skeleton-forming cells, *Ameba*-like cells, sperm-forming cells, and egg-forming cells. Covering cells give protection, feeding cells obtain food, skeleton-formers provide support, and so on. No single sponge cell can do all of these things.

Division of labor is much more complicated in higher animals than it is in the sponges. Higher animals not only have more kinds of cells, but the cells are organized in more complex ways. There are no organs in the sponge and, consequently, there are no systems.

Because a sponge is so simple, it can sometimes survive when higher forms could not. If you were to cut a sponge into little pieces and throw them back in the water many of them would live. Each piece has all the cell types in it. Each can live and grow into a new sponge if it is in a good environment.

The coelenterate phylum. The ***coelenterates*** (suh-*len*-ter-ayts) include the *hydras*, *jellyfish*, *sea anemones* (uh-*nem*-oh-neez), and *corals*. Most of them live in the sea. They usually have delicate, filmy bodies. *Hydra* is the only member of this phylum that is really common in fresh water. We shall study it first, because of its simple structure. It will help you to understand the basic body organization of all the animals in the phylum.

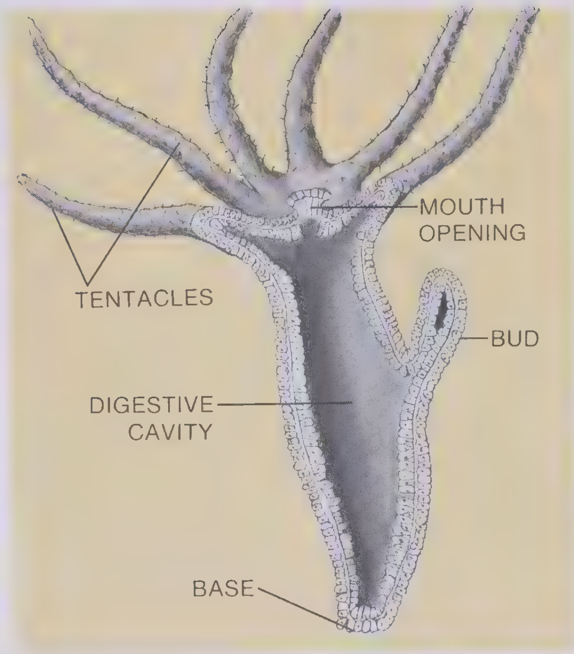


Fig. 27-4. This diagram shows the cell structure of a *Hydra*.

The structure of the Hydra. In Chapter 7 you studied the types of reproduction carried on by *Hydra*. As you will remember, it has a tube-shaped body with a mouth opening at the top. A ring of tentacles surrounds the mouth. Although the small animal is common, you have probably never noticed it. Many *Hydras* are only about one-eighth inch long.

Figure 27-4 is a diagram of *Hydra*. As you see, its body wall has two layers of cells. The tentacles are hollow and have the same cell layers. Tentacles are really long, slender parts that extend outward from the body wall.

The hollow space inside *Hydra* is its digestive cavity. We might say that the *Hydra* is all stomach! The mouth

is the only opening into this digestive cavity. Food must enter through the mouth, and undigested materials leave through it. Cells lining the cavity produce digestive juice, which dissolves the food. Dissolved food molecules can then enter the inner layer of cells through their cell membranes. These cells also have the *Ameba*-like ability to take in small solid particles. Some of the digested food passes on from the inner cells to the outer cell layer.

Hydra can move around, but most of the time it stays in one place with its base attached to some support. Its tentacles trail out into the water. It can slide along slowly on its base. It can also turn "handsprings." The body bends over, and the tentacles touch the ground. Then the body swings up and over. In this way *Hydra* moves end over end.

How Hydra catches and kills its food. *Hydra* is a hunter. It lives on other small animals. *Hydra* kills its victim by stinging it to death. *Stinging cells* are found all over the body of the animal but are especially numerous on the tentacles. One type of stinging cell shoots out a tiny barbed thread which sticks into the prey and injects poison. Another type of cell shoots out a thread which becomes tangled up in the legs or little hairs on the body of the victim and keeps it from escaping.

Fig. 27-5. A *Hydra* catching a waterflea. Sooner or later the waterflea touches a tentacle. (Eric V. Grave)

If you put a live *Hydra* in a small dish of water with a water flea, you will see the hunter in action. You need a magnifying glass or a low-power microscope to watch the water flea swim around and around until it has bad luck and touches a tentacle. Instantly, it stops swimming and never moves again. The stinging cells have done their work. The water flea is not only dead, but it is stuck to the tentacle (see Fig. 27-5). Then *Hydra* slowly takes the dead animal in through the mouth opening to the cavity where it is digested.

Jellyfish. If you could turn *Hydra* upside down and pull the sides of its body out into an umbrella shape you would have a model *jellyfish*. Jellyfish are adapted to drifting in the open sea. There is often jelly-like material between their two cell layers. This gives them their name. The mouth opens downward, with tentacles hanging around it.

Jellyfish sting and eat small fish and other sea animals that swim into their tentacles. Many jellyfish are only a few inches across, but there are some giant ones with bodies six feet across and tentacles as much as 40 feet long.

Jellyfish are often so transparent that people fail to see them in the water. If the filmy, cellophane-like tentacles touch a swimmer's skin, he does not enjoy the sensation. The thousands of stinging cells that puncture his skin produce painful blisters. Usually this is not very serious, but people have been killed when they got too many stings.

Fig. 27-6. A jellyfish. This coelenterate drifts in the open sea and lives on small fish which it catches by means of its tentacles. (R. C. Hermes/Annan Photo Features)

Sea anemones. The *sea anemones* look like they might be giant hydras. They may be several inches high, with hundreds of short tentacles around the mouth. Many are brightly colored, and look like beautiful, big flowers. This is why they are named after a flower—the anemone. But they definitely are animals. Like *Hydra* they feed on small animals coming near the tentacles.

You can find sea anemones along some seacoasts at low tide. A few people have kept them alive in large tanks of sea water. They are most attractive and a group of them looks

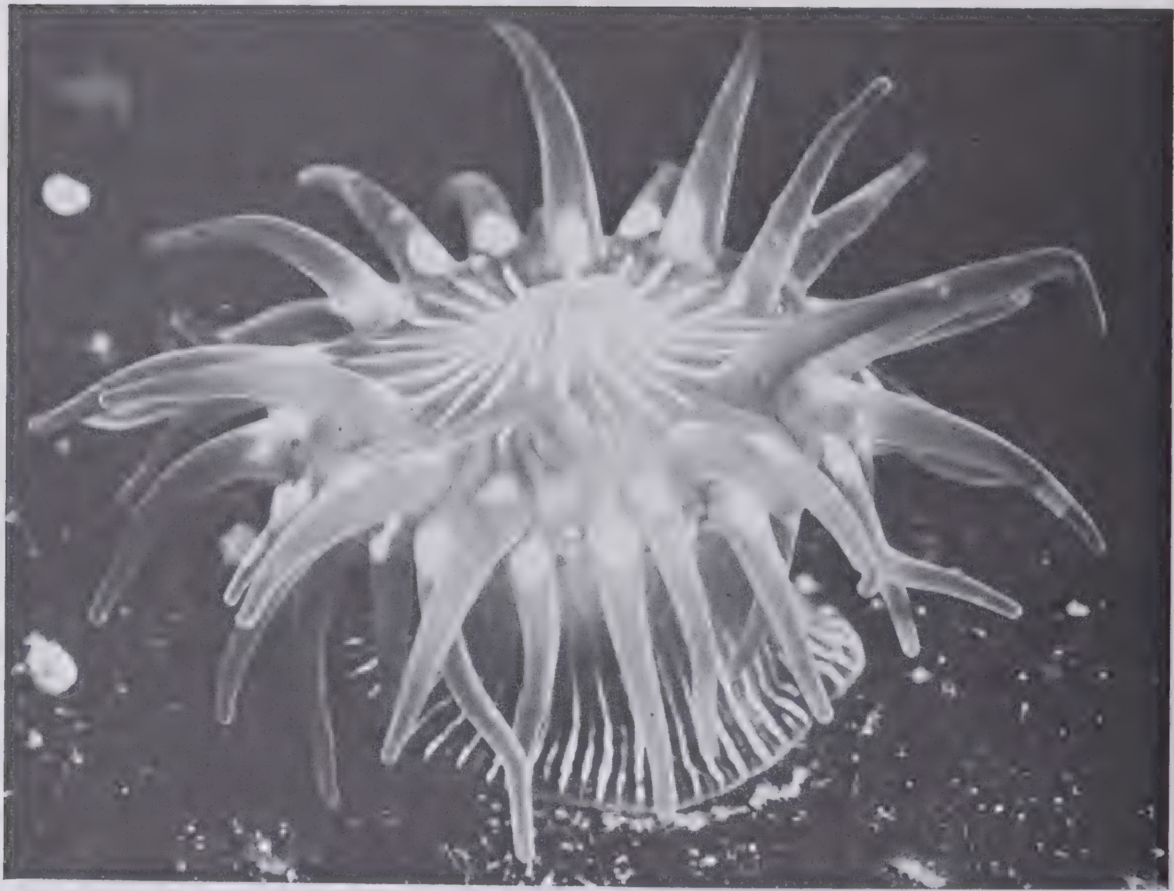


Fig. 27-7. A sea anemone. It looks and acts very much like a giant, tough-bodied *Hydra*. These tentacles can sting small fish to death. (John W. Evans)

like a flower garden—but this garden must be fed a bucket of live minnows every so often!

The corals. *Corals* are important to man because they build ***coral reefs.*** A reef is a shallow, rocky ridge under water. The individual coral animal is similar to *Hydra*, but is usually larger. Each one forms a limestone crater around its body. The animals duck into these craters for protection and reach out with their tentacles for food. These little coral animals live in large groups, with their limestone craters connected so as to form one big mass. Corals multiply by budding and build the reef higher and wider. Some reefs even stick out above water at low tide. Sponges and algae also help to build up these reefs.

Coral reefs appear only in shallow, warm seas. Bermuda, Florida, and the West Indies all have coral reefs, but the best examples are found in the Pacific. Most of the islands of the South Seas have coral reefs around them. These act like breakwaters, protecting the shore from wave erosion. The biggest coral reef in the world is the

Fig. 27-8. Several kinds of coral skeletons on a coral reef. (Courtesy of The American Museum of Natural History)

Fig. 27-9. This photograph shows several kinds of coral animals. Each is similar to *Hydra* and each one is surrounded by a tiny crater of limestone. (William M. Stephens)

Great Barrier Reef of Australia. It is 1,100 miles long. Coral reefs are very irregular, with many caves and hollows in them. They are good hiding places for all sorts of sea animals—fish, crabs, octopuses, and many others.

A coral reef in the right place can make a protected harbor. In the wrong place, it can wreck a ship. This effect upon shipping makes the corals important to man. The long line of islands known as the Florida Keys is really a line of old coral reefs. They were formed many years ago when the sea level was higher than it is today.

ACTIVITY

Observing Hydra. From a pond or from a scientific supply company obtain live *Hydra* and (in a separate culture) live specimens of some small crustacean such as *Daphnia* or *Cyclops*.

Place a live *Hydra* in water in a small glass dish and examine it under a hand lens or a binocular microscope. Can you see it move? How long is it? What does it do

when you poke it with a pencil point? Notice how it stretches out its tentacles when it is left undisturbed.

Place a small crustacean in the dish and watch. The crustacean swims round the dish. Sooner or later it will touch the tentacles of the *Hydra*. What happens then?

Pour some of the crustacean culture in with the *Hydra* culture each day. Under these conditions the *Hydra* culture will grow and reproduce. Watch for animals with buds on them. You will probably not find any producing eggs or sperms, but, if you do, lift one of them out with a large pipette, and place it in a small, crystal watch glass. Examine it under the low power of a microscope. Is it producing egg cells, or sperms, or both?

CHECK YOUR FACTS

1. **What do we mean by division of labor? How does a sponge illustrate division of labor?**
2. **How do sponges get food? How do they digest it?**
3. **How are sponges gathered commercially?**
4. **In what way is digestion in *Hydra* different from that in the sponge? In what way is it similar?**
5. **How does *Hydra* get its food?**
6. **What are two ways in which *Hydra* reproduces?**
7. **How many layers of cells are there in the body wall of a coelenterate? Do coelenterates have tissues? Organs? Systems? Explain.**
8. **Briefly describe the appearance of jellyfish, sea anemones, and corals.**
9. **What makes corals important to man?**

CHAPTER

28

Flatworms and Roundworms

When we call something a worm we are not classifying it. We are describing it. The word *worm* simply means that the animal we are talking about is long and has a soft body. We shall study three phyla of worms. Calling them worms does not mean that they are closely related.

The flatworms. A good example of a ***flatworm*** is *Planaria* (plah-*nair*-ee-uh). This little worm really is flat and it is about half an inch long. It lives under rocks and leaves in freshwater streams. You might find one by leaving a small piece of raw meat or liver in the water for a few hours. *Planaria* is sometimes attracted to meat and may be found crawling on it. Of course, a crayfish may come along and eat the meat first!

Another way to get flatworms is to scoop up the dead leaves and twigs from the bottom of a clear, cold pond. There can be a little mud in the material you collect. Spread this material about an inch deep in the bottom of an aquarium, battery jar, or large screw-top jar. Fill the jar with pond water. During the next few days watch for flatworms crawling around on the glass. They were living in the rubbish on the pond bottom. This gives you a chance to see them. They will not all be in the genus *Planaria*, but they will be similar types.

Planaria moves by means of two layers of muscles in its body wall and by thousands of cilia which cover its lower surface.

The mouth is on the underside a little back of the middle. *Planaria* can push its throat out through this to form a flexible tube. This tube moves around constantly in search of food (Fig. 28-1). At other times the throat is pulled back inside the mouth. *Planaria* eats decaying bits of plant or animal material. It also eats live insect larvae or other small water animals if they are small enough to enter the tube and be swallowed, and move slowly enough to be caught.

The throat opens into an ***intestine.*** The intestine of an animal is its main digestive organ. A stomach is really an enlarged section of the intestine. In *Planaria* the intestine has three main branches, as shown in Figure 28-2. The mouth is its only connection with the outside. In this respect *Planaria* is like the *Hydra*. Undigested materials must pass out through the mouth opening.

In its head *Planaria* has a mass of nerve cells which form the brain. Two

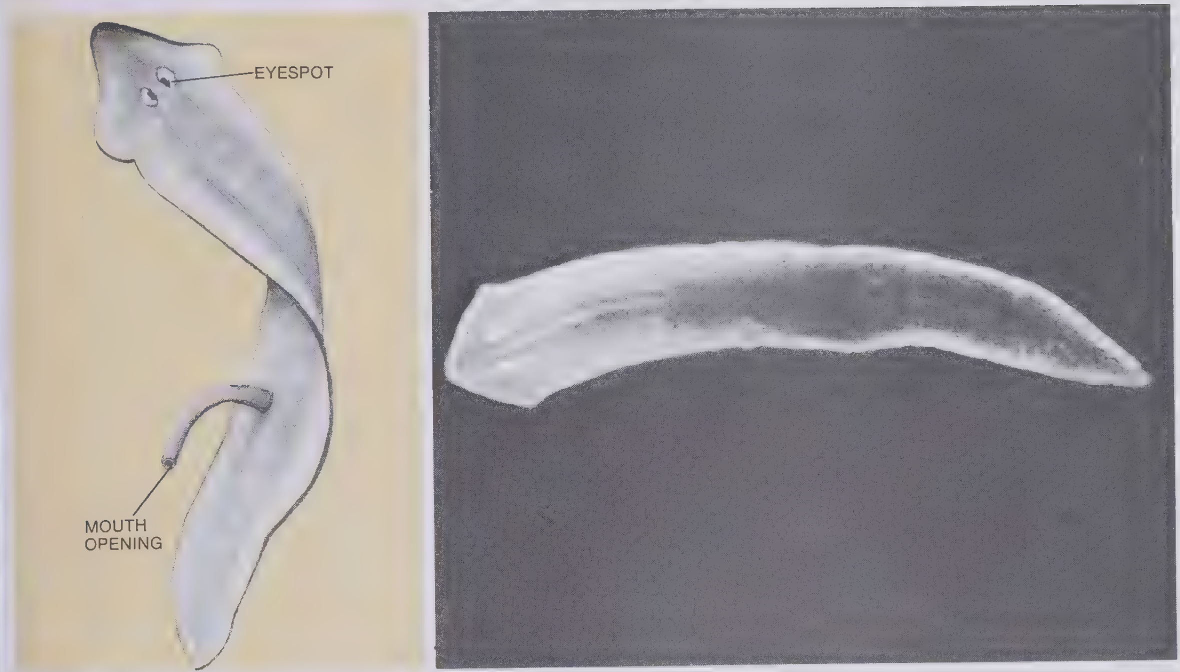


Fig. 28-1. On the left is a drawing to show how flat *Planaria* actually is. Note how the throat sticks out like a tube so as to take in food. On the right is a photograph of a living *Planaria*. (Hugh Spencer)

large nerves go back through the body from the brain, as shown in Figure 28-2. These large nerves give off branch nerves to all parts of the body. This simple nervous system controls the various things that this animal can do.

The eyespots of *Planaria* allow the animal to tell light from dark and the direction the light is coming from. *Planaria* moves away from bright light.

As you see, *Planaria* is much better organized than *Hydra*. *Hydra* has some tissues. *Planaria* has several tissues and some organs and systems. We have mentioned the nervous and digestive systems. It also has covering, reproductive, and excretory systems. So *Planaria* has six systems out of the possible ten which are listed in Chapter 6.

Parasitic flatworms. *Planaria* and similar flatworms get their food from the water. They are really variety eaters. There are other members of the flatworm phylum which live as parasites in larger animals. These include the flukes and the tapeworms. They get their food entirely from the animal host.

Dogs, cats, chickens, cows, and other domestic animals usually contain a variety of parasitic worms. These may be tapeworms or flukes, or they may be members of another phylum of worms. Most of these worms are well adapted to the host and do not cause great harm. After all, if the host dies, so does the parasite. Natural selection tends to get rid of parasites that handicap their hosts too much.

The ***flukes*** look something like *Planaria*. Some live in the liver, and some

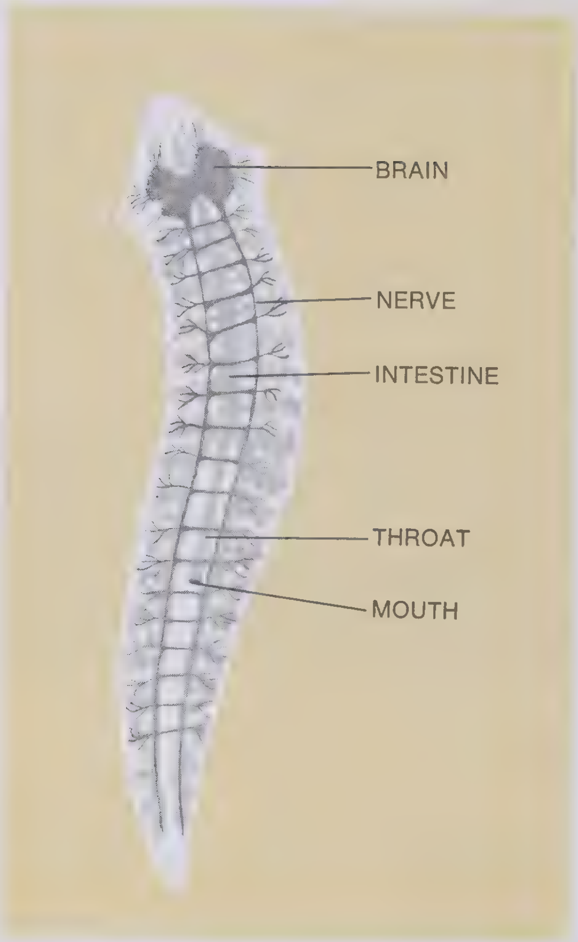


Fig. 28-2. The digestive and nervous systems of *Planaria*. See how the brain connects with the entire body by way of nerves. See also how the intestine branches all over the body. Is this in any way connected with the fact that these worms have no blood?

live in other parts of their hosts. Blood flukes and liver flukes are serious parasites of man in many parts of Africa and Asia. In America there is a fluke which lives in the livers of sheep and causes some trouble.

Tapeworms. Adult *tapeworms* live in the intestines of higher animals including man. They are adapted in many ways to a parasitic life. They have no mouth or intestine. They live in the intestine of the host and absorb molecules of food that the host has digested. They have no eyes and do not move around much. Their ability to reproduce is highly developed.

The life of a parasite is very easy once it has found a host. The host gets food for both of them. The host avoids enemies. All of the ordinary dangers and problems which an animal must meet are taken care of for the parasite by its host. The one big problem a parasite has is finding a host. Most young parasites fail to do this. A high rate of reproduction is needed if the species is to survive. Tapeworms have a very high reproduction rate. They produce millions of eggs.

Figure 28-3 shows part of an adult tapeworm. The head is really just a special organ for hanging on to the host. It has four suction cups and a ring of hooks. With these the head clamps on the lining of the host's intestine. Food keeps moving along through the intestine of the host, and the worm needs some way to anchor itself in place.

Just back of the head the tapeworm keeps budding off new sections. The older sections are pushed farther and farther back as new ones form. The sections grow bigger as they become older. The result of this is a long, flat worm which really looks like a piece of tape. There are many species of tapeworms. You would need a microscope to study some of them. Others are much larger. One tapeworm that lives in the human body is less than an inch long. Another type that attacks man gets to be 50 feet long.

The tapeworm life cycle. Each section of a tapeworm contains a complete

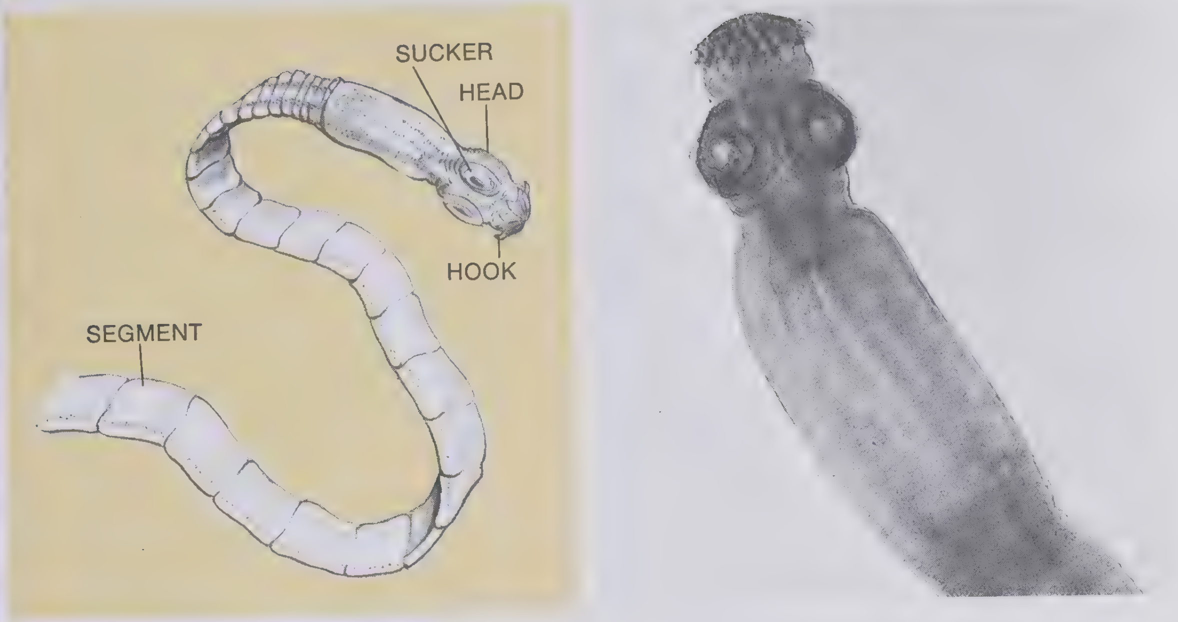


Fig. 28-3. Left: the head end of a tapeworm. This is a type that lives in man. Its alternate host is the pig. Right: a photograph of an adult tapeworm. (Walter Dawn)

set of male and female reproductive organs. Old sections near the end of a tapeworm's body are much larger than new sections up near the head. The old sections are large and swollen because they are now filled with hundreds or thousands of tiny eggs. These egg-filled sections break loose when they reach the end of the worm. They are carried along through the host's intestine with the digested food. Finally they leave the host in the ***feces*** *(fee-*seez*)*. Feces are the undigested wastes that come from the intestines of an animal. The feces fall to the ground and decay. So do the tapeworm sections, but the eggs remain alive. They get scattered all over the ground.

The eggs may happen to be swallowed by some animal with its food. If it is the right kind of animal for that kind of tapeworm, the eggs will hatch and grow inside the animal's body. Of course, most tapeworm eggs are not swallowed or they are swallowed by the wrong animal. Then they do not survive. This is why a high rate of reproduction is one of the adaptations of a parasite.

Tapeworms usually have two hosts. The adult worm lives in one kind of animal, but the larva lives in another kind of animal. The host that has the adult worm is called the *main host*. The host with the larval worm is the *alternate host*.

Man is the main host of several tapeworm species. The alternate hosts are such animals as pigs, cows, and fish. The most common tapeworm found in dogs has rabbits as its alternate hosts.

As an example of the life cycle of a tapeworm let us take the worm that has a cow and man as its two hosts. It is called the *beef tapeworm*. In the cow

the tapeworm egg hatches into a little larva which travels in the bloodstream for a few days and then settles in a muscle. There it forms a *cyst*, or capsule, around itself. Inside the cyst the little tapeworm forms a head and a few sections. The cyst is small and not easily seen.

Now, suppose that the cow containing the tapeworm cysts is used for meat. If the beef is not cooked thoroughly, the worm may still be alive when it is eaten by a person. The worm will come out of its cyst, clamp on to the intestine lining, and begin to grow. When it is fully grown, segments containing eggs pass out of the person's body mixed in the feces. If any of this feces is left on the surface of the ground, some of the eggs may stick to grass blades. Cows swallow the grass, and the cycle starts over again.

Tapeworm eggs of this species have little chance of reaching the alternate host if sewage is disposed of in sanitary ways. For this reason few people get beef tapeworms in countries like the United States or Canada. But some human wastes are allowed to lie out on the ground and many people like to eat rare beef. So some people become hosts to this worm. Doctors can cure people of tapeworm by giving medicines that will either kill the worm or, at least, make it relax and let go of the intestine lining. It then passes out of the body with solid waste materials.

Some people do not even know when they have a tapeworm. It does not upset them enough to make them realize that anything is wrong. Others feel fairly sick. It depends partly on which kind of tapeworm they have. Some types are much more dangerous than the beef tapeworm.

Importance of the flatworms. The free-living flatworms like *Planaria* probably do not have any great effect upon the communities in which they live. Of course, they do fit into various food chains. The parasitic flatworms are of more importance because of their effect upon the hosts they attack. They seldom kill their hosts, but they do slow them down. One man counted over 50 tapeworm cysts in a single cubic inch of caribou meat (the caribou is a northern species of deer). This did not seem to handicap the caribou too much, but it surely would have felt better without all those worms!

The roundworms. It is likely that you have never seen a ***roundworm.*** Yet roundworms are among the most successful animals. They live almost everywhere—in water, in soil, and as parasites in higher animals and plants. Most free-living ones are so small that we do not notice them. The parasites include some fairly large types, but they are out of sight in their hosts.

The roundworm phylum does not include the common earthworms, even though they are round. Earthworms belong to a different phylum as we shall see in Chapter 29. The roundworms are slender, round, and not divided into segments like earthworms. Many books and gardening magazines call the roundworms *nematodes (nem*-a-tohds*)*.

The structure of roundworms. The roundworms are only slightly more complex than the flatworms, but their body organization is more like that of

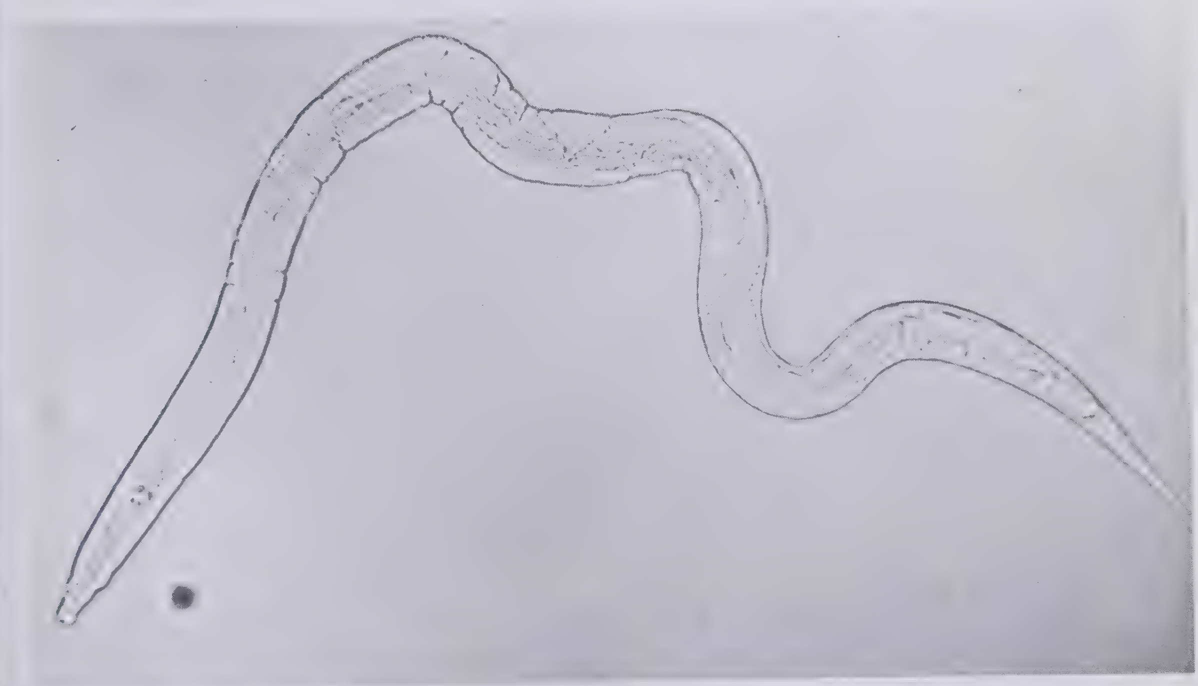
the higher animals. There is a body wall made up of a covering layer and two layers of muscles. Inside this, the worm is hollow. The intestine passes through this hollow space. It is a tube with openings at each end—the mouth and the ***anus*** *(ay*-nus*)*. Thus, the worm takes in food through the mouth, digests it, and absorbs it as it moves along the intestine. Wastes pass out through the anus. There is no mixing of old and new food, as in *Hydra* and *Planaria*. This arrangement is found in all of the higher animals.

Free-living roundworms. Many tiny roundworms live in the mud on the bottoms of lakes, ponds, and streams. Others live in soil. Some of those in soil attack the roots of plants and do real damage. They would be far more destructive if it were not for certain molds living in the soil. These molds form sticky loops of fungus tissue which act as traps. They catch and digest the unfortunate roundworms that crawl into them. Figure 28-4 shows a type of roundworm that may live in homemade cider vinegar. These roundworms are perfectly harmless. They are often called "vinegar eels."

Parasitic roundworms. The roundworms are by far the most numerous of all the parasitic worms. The three types we shall study are the ones most often found in this part of the world.

Ascaris *(as*-ka-ris*)* is the most common parasitic roundworm. One species that attacks man is about eight inches long. It lives in the human intestine. *Ascaris* feeds on partly digested food.

Fig. 28-4. A typical roundworm. You can see the intestine through the body wall. This is the tiny worm that lives in some samples of vinegar and is called a vinegar eel. (Hugh Spencer)



A few of these worms in the intestine may make the host feel sick, but more often they seem to cause little trouble. But a lot of worms can be dangerous, and when a number of worms are present the host is sure to suffer.

The female worms lay millions of microscopic eggs which leave the host in the feces. In regions without sanitary sewage disposal, the eggs are often present in the soil. People may swallow *Ascaris* eggs when they eat vegetables grown in such soil. Or they may get them from their own hands if they did not wash before eating. In some countries of Asia, human sewage is used as fertilizer for growing farm crops. This is good farming, for it returns minerals to the soil; but it is poor sanitation. Nearly everyone there has *Ascaris*. In America it is children who are most likely to get the worm. They like to play in the dirt, and they are careless about washing their hands.

Although *Ascaris* usually is not dangerous, it sometimes causes real trouble. Masses of these worms can block a human intestine. The adult worms sometimes bore out through the intestine wall and into the main body cavity, causing infection. They may wander about in the body and be found in the liver or some other organ. In any of these cases death may result.

As in the case of tapeworms, doctors have medicines that will drive *Ascaris* worms from the intestine.

Hookworm. Adult ***hookworms*** are only about half an inch long, but thousands may live in the intestine at once. They use blood from the intestine lining as food. This steady loss of blood weakens the host so that he does not feel well enough to do a good day's work. Such people are often called lazy. Actually they are sick.

Eggs laid by these worms leave the host in the feces and hatch on the ground. The larvae rest on the soil or on blades of grass. If someone brushes against them they stick to his skin. Then they bore right through the skin and into the bloodstream. They are so small, however, that you do not feel them entering the skin. After traveling through the blood and lungs of the host, they arrive in the intestine where they start feeding on blood.

Hookworms are found in warm climates, including the southern United

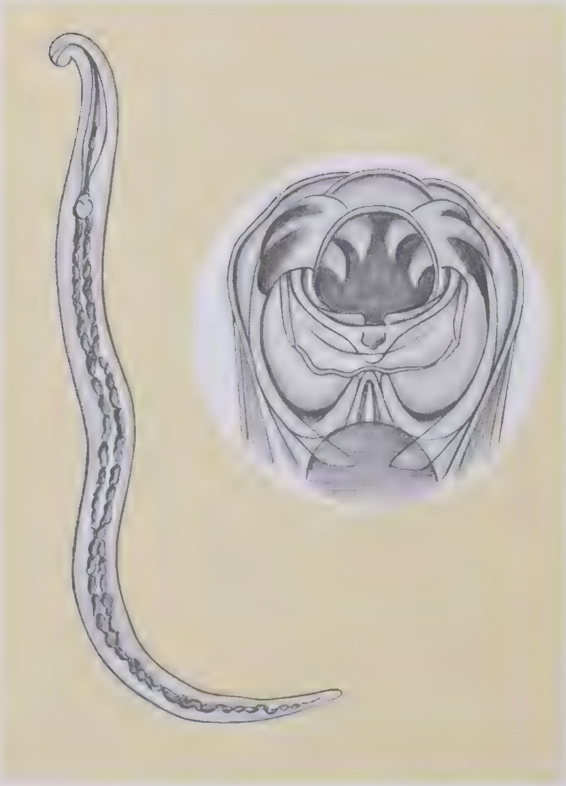


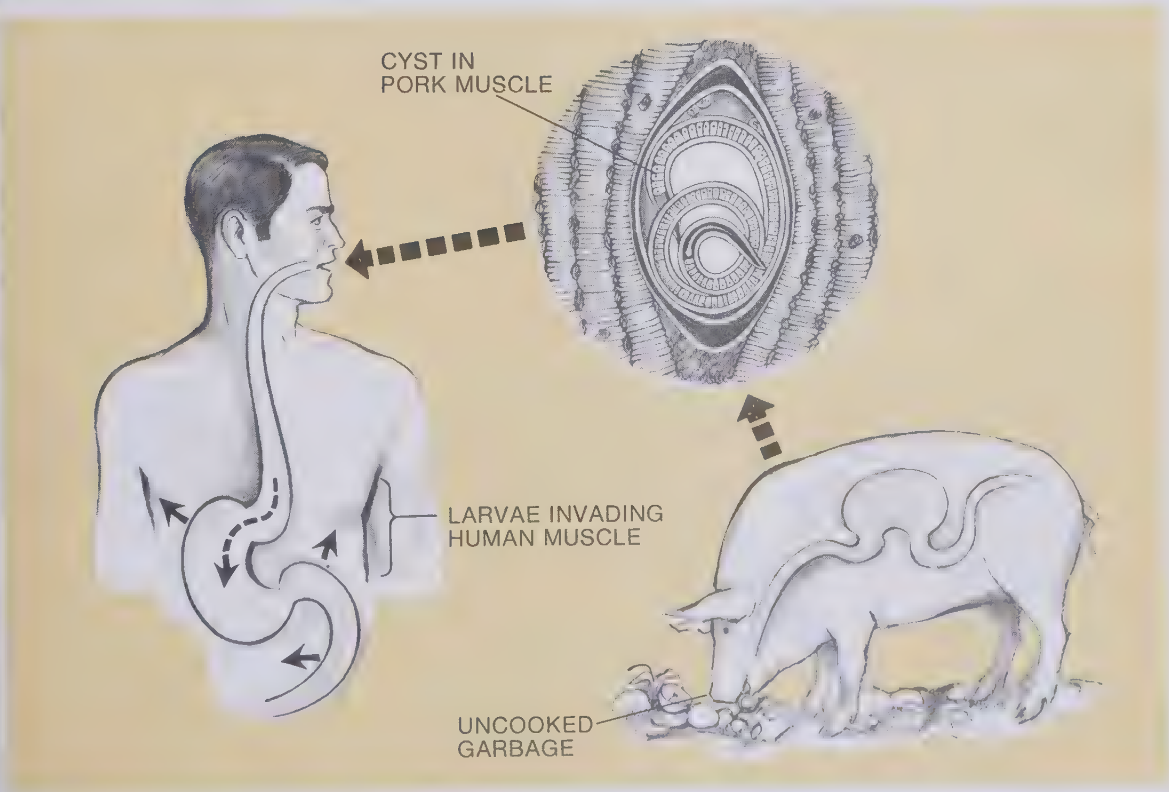
Fig. 28-5. The hookworm. These tiny worms live in human intestines.

States. In colder regions, the worms are killed in the soil by freezing. In some warm countries so many people have hookworm that the whole standard of living is lowered. There are not enough healthy people to do the work. A community can get rid of hookworm by establishing safe disposal of human waste. This prevents the worm eggs from settling on the ground. Individuals can get a good deal of protection by wearing shoes. Why does this help?

Trichina—another of the parasitic roundworms. We said a well-adapted parasite does not destroy its host, but the ***trichina*** (tri-*ky*-na) is a roundworm that may sometimes kill. The adult trichina worm is less than one-fourth inch long and lives in the intestine of the host. The eggs hatch in the oviduct of the female worm. She injects the larvae into the blood vessels of the intestine. From there they travel in the bloodstream to all parts of the host's body. Finally they bore into the muscles and form *cysts*. When another animal eats this host, the young worms come out of their cysts, grow up, and start producing young of their own. Notice that these worms never leave the body of a host. They are passed on as host eats host.

When trichina worms attack man, he suffers from aching pains and has a fever. This happens while the young worms are boring into the muscles to form cysts. If too many worms are present the person may die, or, a part

Fig. 28-6. Young trichina worm in the muscle of a pig.



of the body may be paralyzed. Once the worms have settled down in the muscle they usually cause little discomfort.

People get trichina worms from eating undercooked meat. This meat must come from an animal that has live trichina cysts in its muscles. Usually this is a pig. This is why pork must be well cooked before it is eaten.

Pigs, rats, and a number of other animals are hosts of the trichina worm. Pigs may eat dead rats or dead pigs that contain the worm cysts. Pigs may also eat meat scraps in uncooked garbage that contain the cysts. Most states now require that all garbage be steam cooked before it is fed to pigs. This has greatly reduced the number of trichina cases. More effective rat control has also helped. But even so, to be completely safe from these parasites meat should be cooked long enough to get it thoroughly hot all the way through. Smoked sausage and ham cause the most trouble because they look and taste good even when they are undercooked.

ACTIVITY

Observing worms. Make a study of *Planaria* and the vinegar eel. You might collect *Planaria* from a pond. Look for vinegar eels in old, homemade vinegar. Or, use worms bought from a scientific supply company.

Observe *Planaria* under a hand lens or with a binocular microscope. Observe the vinegar eels under the low power of a regular microscope. Write a paragraph describing your observations of these two worms. In what ways does the flatworm *(Planaria)* differ from the roundworm (vinegar eel)?

See if you can find roundworms or flatworms in pond cultures which have been set up in your classroom. Under the microscope can you see the intestines at work inside the transparent bodies of the roundworms?

Study prepared slides of tapeworms, trichina worms, hookworms, or any other parasitic worms which your school may have.

CHECK YOUR FACTS

1. Compare the body organization of the flatworms and the roundworms.
2. What body systems does *Planaria* have which *Hydra* does not have?
3. How do people get tapeworms?
4. How does a tapeworm get into the alternate host?
5. How can we protect ourselves from tapeworms?
6. What are flukes?
7. What different environments do roundworms live in?
8. For each of the following worms, tell (a) how it passes from host to host, (b) what sort of damage it does, (c) how a person may protect himself from it, and (d) how a community can fight it: tapeworm, *Ascaris,* hookworm, trichina worm.

CHAPTER

29

Segmented Worms

The phylum we shall study in this chapter includes all the worms that have their bodies divided into sections, except the tapeworms. They are sometimes called the ***segmented worms.*** *Segment* means a part, or section, of something. The earthworms belong in this phylum. When you look at an earthworm you can see the cross lines marking the segments. The members of this phylum are much more complex than any animal you have studied so far.

Earthworms have well-developed organs and systems. Figure 29-2 shows some of the inside structures of an ***earthworm.*** There is a body wall consisting of a surface covering and two layers of muscles. Fibers of the outer muscle layer go around the body. When they contract the worm becomes long and thin. The inner muscles run lengthwise. When they contract the worm becomes short and thick.

Inside the body wall is a *body cavity* through which the intestine passes. The front part of the intestine is modified to form special structures. There is a muscular *throat* that sucks foods into the mouth, a *crop* that holds foods, and a *gizzard* that grinds food. Then the tube-shaped *intestine* runs the length of the worm. Above the throat there is a tiny *brain* connected to a *nerve cord* which lies under the intestine. This nervous system controls the actions of the worm.

An earthworm has red blood which moves around the body in *blood vessels*. It also has ten hearts that help to keep the blood moving. Actually these hearts are just short sections of blood vessels that contract and force the blood along. The blood carries dissolved food from the intestine to all parts of the body. It also carries oxygen from the body surface to other cells of the body.

Fig. 29-1. An earthworm. These worms live in the ground where they will not dry out. In what ways are these worms useful to man? (Stephen Dalton)

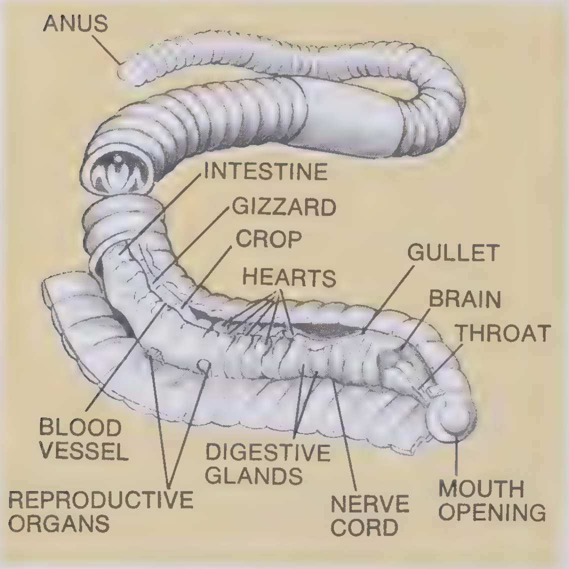


Fig. 29-2. The inner structure of an earthworm. Do not expect every worm to be exactly like this because there are over 90 different species of earthworms in the United States and Canada.

Two little tubes are present in most of the worm's segments. Liquid wastes from the body cavity pass into these tubes. The tubes lead to pores in the body wall. The wastes pass out of the body through these pores. You can see that the little tubes are the excretory system of an earthworm. They do the same work that the kidneys do in higher animals.

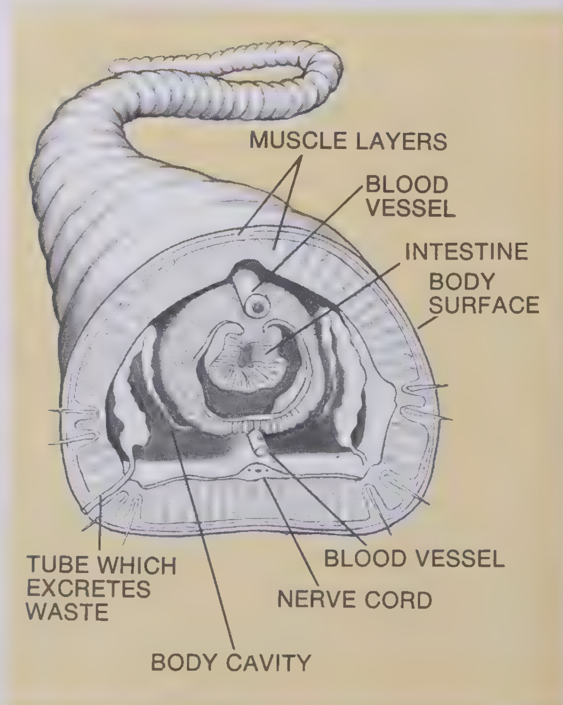
Earthworms have sex organs. A single worm has both male and female organs. Pairs of earthworms come together and exchange sperms. Eggs and sperms are placed in little egg cases that are left in the soil. In time, the eggs hatch. Then the young worms leave the egg cases.

As you can see, earthworms are fairly complex little animals. They have well-developed organs and systems. Figure 29-3 shows a cross-cut view of an earthworm's body.

The importance of earthworms. An earthworm digs through the soil by eating dirt. The soil passes completely through the worm and out of its anus. Any bits of humus in the soil are digested. You can see why worms do not live in poor soil. It just does not contain enough food for them. This digging and stirring loosens the soil and allows rainwater and air to enter. In this way earthworms improve the soil for the growth of plant roots.

Earthworms have one odd habit. They come to the surface to get rid of some of their solid wastes or feces. These feces are mostly small soil particles. So the worms keep bringing up fine soil particles to the surface and in time this activity greatly improves

Fig. 29-3. A cross section through an earthworm body. The bristles on its body help it to grip the ground when it crawls.



the soil. That is why earthworms are so valuable to gardeners and vegetable growers.

Other segmented worms. Sandworms, which live in the sea, are more active animals than earthworms. You see one of them in Figure 29-4. These worms burrow to capture other small animals with their pincerlike jaws. Sometimes they come out of their burrows and swim about. In Figure 29-4 you can see that a sandworm has many little flaps on each side of its body. They are used in swimming and they also absorb oxygen from the water. These little flaps are a simple sort of respiratory system. They do the job that gills do in some other animals.

A sandworm has four eyespots and a group of tentacles on its head. These are sense organs. Because the sandworm leads a more active life than an earthworm, it needs sense organs that are better developed.

Some segmented worms that are filter feeders also live in the sea. They have long, feather-like organs all around their mouths. They reach out from their burrows with these organs to catch drifting bits of food in the water.

Segmented worms are also found in fresh water. Many lakes and streams have hundreds of small segmented worms living on every square yard of bottom. These worms usually have their front ends in the mud and their back ends waving in the water to get oxygen.

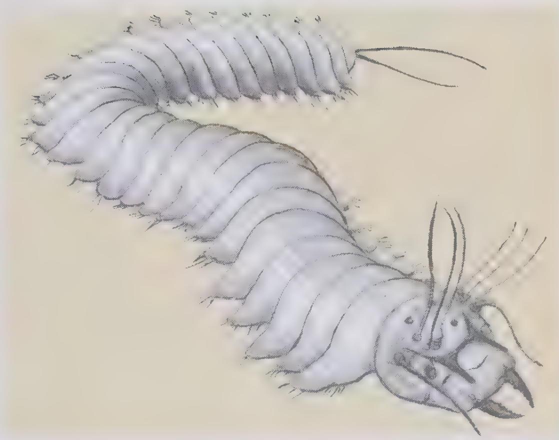


Fig. 29-4. A sandworm. Many worms like this live in shallow sea water along the shoreline.

Fig. 29-5. The leech shown here is another type of segmented worm. (Hugh Spencer from National Audubon Society)

Leeches are segmented worms which sometimes get on the skin of swimmers and suck blood. Perhaps you call them "blood suckers." They are sometimes found on turtles or on fish. A leech has a suction cup at each end of its body. You can see the one at the front end in Figure 29-5. It is around the mouth. Inside the mouth are three small, hard jaws. These jaws are used to cut the skin of the host so that blood will flow. You feel no pain when a leech bites you. Its saliva con-

tains a pain killer. Most leeches are found in fresh water. A few live in the sea, or in wet places on land. Not all leeches suck the blood of larger animals. Many of them feed upon water insects. When leeches are hunting their food they may crawl along like other worms. They also use a waving motion of their bodies to swim through the water.

ACTIVITY

Dissecting an earthworm. Study the inside structure of a preserved earthworm. Most scientific suppliers sell these worms which are better for dissection than fresh ones. The organs of fresh worms sag out of shape and are hard to recognize. Figures 29-2 and 29-3 will help you identify the parts of the worm. Place the worm on a cork slab or in a dissection pan. Use dissecting scissors to cut through the body wall along the back. Lift the lower tip of your scissors as you cut. This will keep you from damaging the inside parts. Run the cut along the worm's top for about the front third of its length. Peel the body wall outward and pin it down. Notice the thin partitions that divide the body cavity into compartments. The soft white structures near the front end are male and female sex organs and other glands. Remove them so that you can see the ten hearts. Try to identify the upper blood vessel, esophagus, crop, gizzard, and intestine. If you are careful you may be able to locate the white, small brain near the head end.

CHECK YOUR FACTS

1. **What do we mean when we say that an earthworm is segmented? Are most of the segments alike?**
2. **How do earthworms dig?**
3. **How do earthworms improve the soil?**
4. **Describe the structure of an earthworm. Make a drawing if you wish.**
5. **What structures does the sandworm have that help it to lead a more active life than an earthworm?**
6. **What do leeches eat? How do they get their food?**

CHAPTER

30

The Mollusks

If you have been around bodies of water very much you have seen ***mollusks*** *(mol-usks)*. This phylum includes snails, clams, and oysters. Perhaps you have picked up some of their shells to carry home as souvenirs. Many people enjoy the hobby of collecting shells.

You do not even have to go to water to find mollusks. Some snails and slugs live on land. A slug looks like a snail without a shell. You may have seen silvery streaks of slime on the ground on a damp summer morning. These were probably laid down by slugs as they crawled during the night. Slugs and land snails always make a ribbon of slime to crawl on. Their soft bodies do not touch the rough ground.

Structure of a clam. To get an idea of what mollusks are like, look at Figure 30-1. This is a drawing of a freshwater ***clam.*** It is protected by a double shell. The two parts of the shell are hinged together, and open like the covers of a book. A piece of muscular flesh sticks out through the shell opening. This is called the ***foot.*** The clam sticks this foot into the mud to pull itself along.

The space between the edges of the open shell is closed off all around by loose flaps of flesh. But at one end two tubes lead from the outside to the space inside the shell. These tubes are called ***siphons*** *(sy-funs)*. The word *siphon* really means tube. A current of water passes into the animal through one siphon and out through the other.

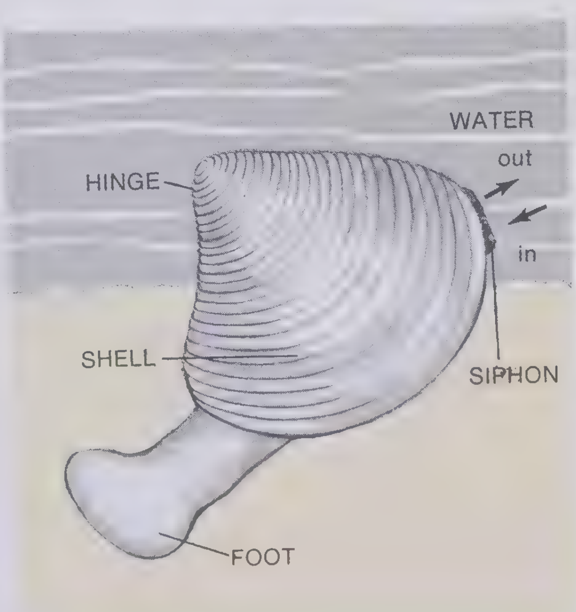


Fig. 30-1. A freshwater clam. The foot pulls the clam slowly through the mud. What is the function of the siphons?

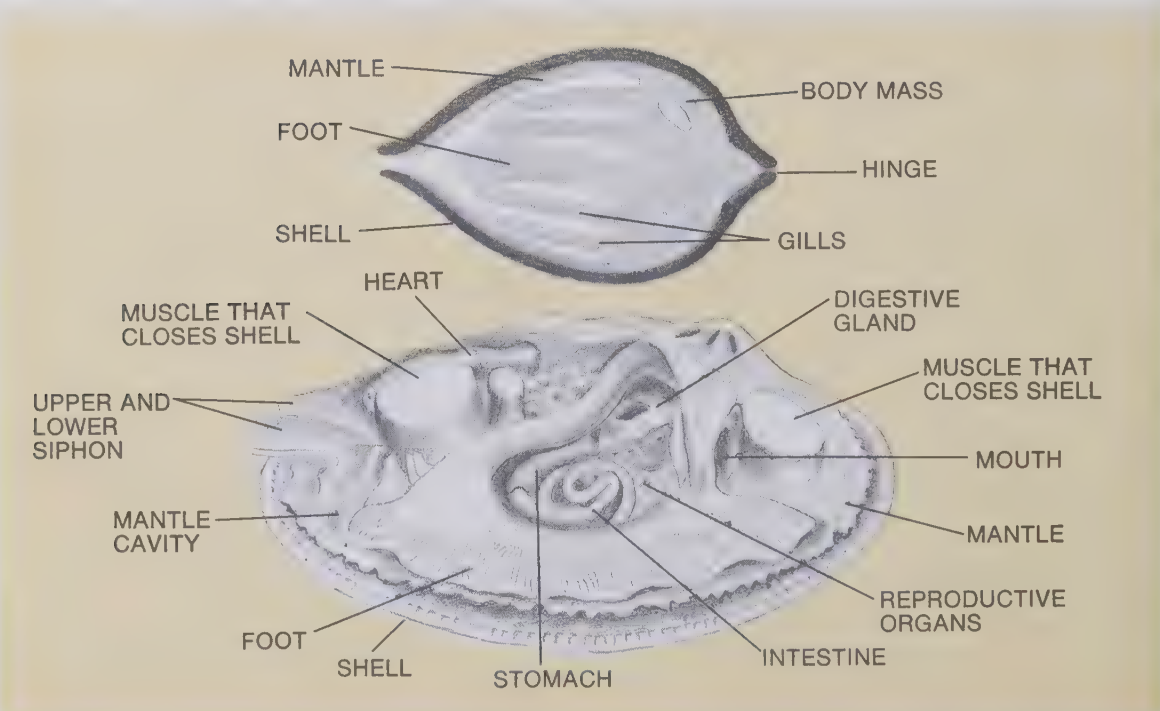
The clam does not move around much. Most of the time it stays still, half buried on the bottom. It does not have to go anywhere because its food comes to it. Like the sponge, it is a filter feeder. The clam gets many small living things from the water that is always passing through its siphons.

Now look at Figure 30-2. It shows the inside of a clam. See how the foot comes down from the main body of the clam. See, also, how two gills hang down on each side of the foot. These gills have many little holes through them, like a sieve. This gives them a great deal of surface area for absorbing oxygen from the water. The gills are also food-catching organs. Food particles in the water stick to the gills. Then the bits of food are pushed along by cilia from the gills to the mouth. See also how the shell is lined with a thin layer of flesh. This layer is called the ***mantle.*** the word mantle means coat. The cells of the mantle produce the shell.

The space with the gills and foot in it is called the ***mantle cavity,*** because it is surrounded by the mantle. The current of water entering the mantle cavity from one siphon passes through the gills and out through the other siphon. The mantle lining is covered with cilia. They beat the water to produce the current. The edges of the mantle form the flaps which close the space between the edges of the shell when it is open.

A clam is a complex animal. It has muscles and a skeleton in the form of its shell. It has an intestine (diges-

Fig. 30-2. Two views of the inside structure of a clam. The animal has been cut open to expose the various organs.



tive system) and gills (respiratory system). It has a heart which pumps blood (circulatory system). The blood carries oxygen and digested food all through the body. The clam has an excretory system to remove wastes from the blood. It has a nervous system to control its movements. We cannot say that it has a brain, because there are three main nerve centers, all about the same size. It has a reproductive system that produces sperms or eggs.

Life history of a clam. The eggs of a freshwater clam hatch in the mantle cavity. They develop into tiny larvae smaller than pinheads. When the shadow of a passing fish falls upon the female clam, she clamps her shell shut. This action shoots water out through her siphon. This water contains a cloud of larvae. They clamp on to the gills or fins of the fish and ride for a while. At this stage they are parasites. Then they drop to the bottom and grow up. This "hitch-hiking" on fish spreads clams through our freshwater streams and lakes. In the ocean young clams and oysters do not do this. They swim about for some time under their own power, using cilia. Then they settle down to life on the bottom.

The classes of mollusks. Freshwater clams belong to one of the big classes of mollusks. It is made up of all those mollusks that have a pair of shells hinged together. This class includes many other clams, oysters, and scallops. In the ocean, adult oysters and many of the clams do not move around at all. They live fastened in one place, to a rock or other object. An oyster has its hinge on one end of its long shell. This end is cemented to some support. Some types of clams have long siphons. They can hide a foot deep in the mud and still get clean water through these siphons. The giant clam of the South Pacific gets to be as big as six feet across and weights several hundred pounds. If you should put your foot into this clam you would frighten it into closing its shell. You might as well be in a bear trap!

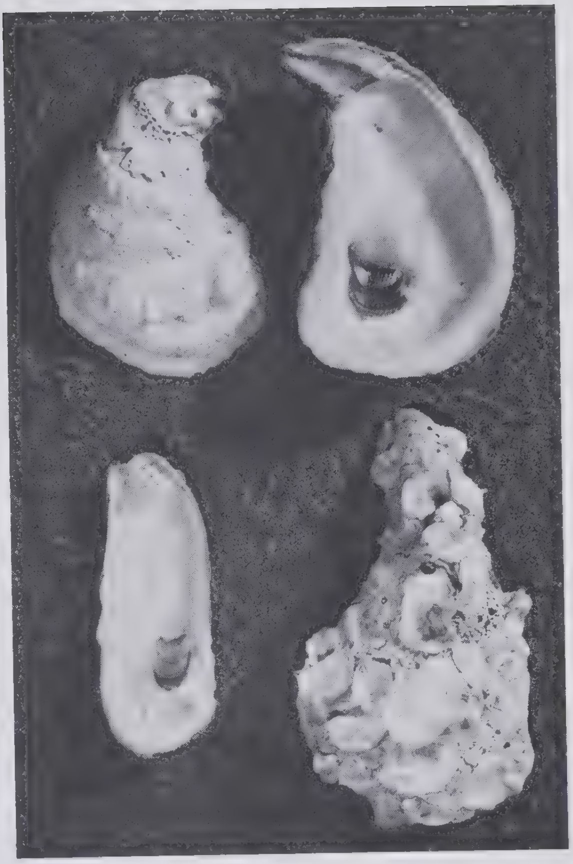


Fig. 30-3. Mollusks produce a great variety of shells. (John H. Gerard from National Audubon Society)

The snail group. There are other important classes of mollusks. They all have the same basic body organization

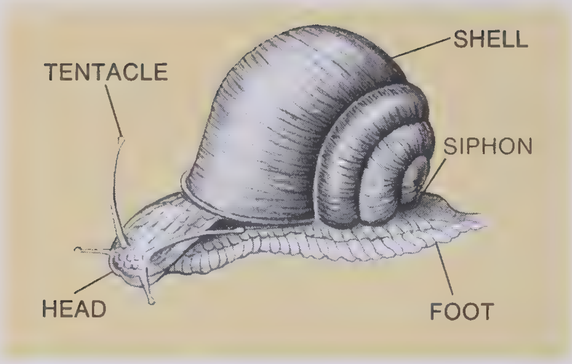


Fig. 30-4. The snail crawls along slowly and scrapes food into its mouth with its file-like tongue.

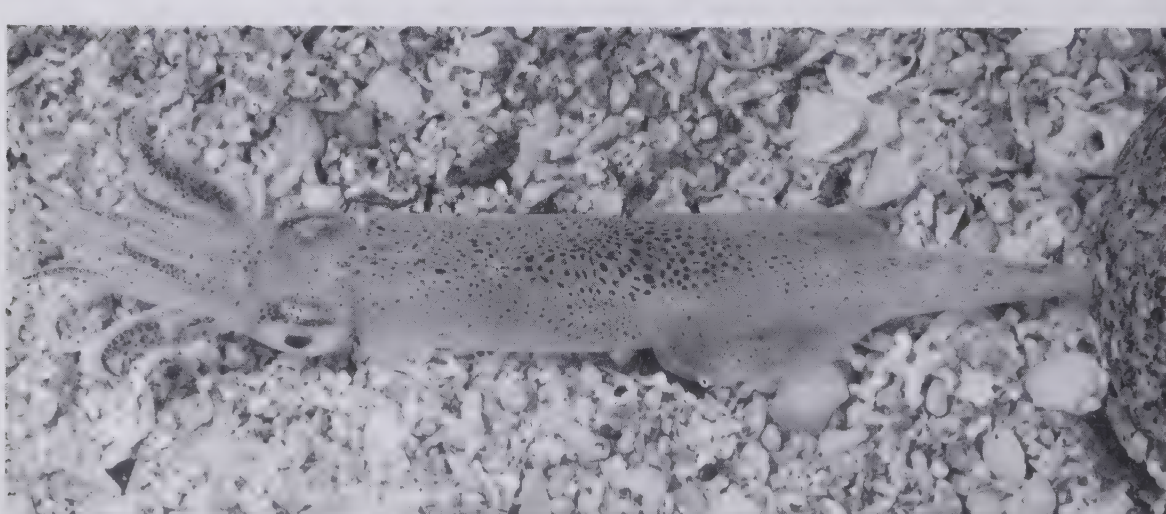
as the clam, but the parts are arranged in a somewhat different way. This adapts them to other ways of living. The snail class is one of these mollusk groups.

Snails have a mantle that forms a single, twisted shell. The vital organs, such as the heart and intestines, are inside the shell. So is the mantle cavity, with its gills. Not all snails, however, have gills. Some have a lung instead. The part that looks to us like the snail's body is mostly its foot. At the front end is the head, with tentacles on it. The snail can feel and taste with these tentacles. Some snails have simple eyes on the ends of them.

Snails have a tongue-like structure covered with tiny sharp teeth. They use this for scraping off bits of food from the surface they are crawling on. Some eat plants. If you put some land snails in a jar you can feed them lettuce. Garden snails and slugs can damage land plants with their scraping tongues. Some water snails eat the film of slime off surfaces under water. This film may contain bacteria or algae. Snails like this help keep an aquarium clean. Some snails, called *drills*, cut holes through thick oyster shells and eat the flesh inside. When a snail is attacked, it pulls its foot and head up inside the shell.

The octopus group. The octopus class is another important group of mollusks. The members of this class have the same parts as other mollusks but arranged in still another way. Look at

Fig. 30-5. A squid. Note that it has the same general parts as other mollusks, but they are arranged differently. (R. H. Noailles)



the ***squid*** in Figure 30-5. The squid has no shell on the outside. The mantle covers part of the body. Inside is the mantle cavity containing gills. In the head area a group of nerve centers form a brain. The outer end of the foot is divided into eight short and two long tentacles. All ten tentacles have suction cups to give them a firm grip. They are used to catch fish and crabs for food. The mouth is in the center of the ring of tentacles. It has a sharp beak with which it can bite off chunks small enough to swallow. On each side of the head is a large eye. These eyes are much like ours. Each eye has a lens and many of the other parts. This is the first animal we have studied with eyes that can see shapes.

An octopus is built about the same way as a squid. Its body is short and rounded instead of having the torpedo shape of a squid. An octopus does not have the two long tentacles. The shape of the octopus adapts it for living on the ocean bottom. A squid swims swiftly in the open sea. When either of these animals is in a hurry, it shoots water out through its siphon. This jet of water sends the octopus or squid streaking away like a rocket. These animals had jet propulsion long before our rocket scientists ever thought of it! A squid can also swim by rippling its fins.

Members of this class have a curious means of defense. They shoot out an inky substance which clouds the water. Hidden in this cloud, they can either swim away or they can attack their prey. What is better fitted for wrestling in the dark than an animal with eight arms?

In spite of stories you may have

Fig. 30-6. An octopus at rest. How does this animal resemble a squid? How is it different from a squid? What environment is each animal adapted to? (R. H. Noailles)

heard, an octopus hardly ever attacks a man.

The octopuses in Atlantic waters are seldom more than four feet across. This is measured from the tip of one tentacle to the tip of an opposite tentacle. Some octopuses in Pacific waters, however, are 30 feet across. Most squids are less than a foot long. But off the west coast of South America are some species that are six to eight feet long. And there are even larger squids, as you shall see.

The smaller octopuses and squids are eaten by people in various parts of the world. They are popular foods in Europe and Japan. Squids are also cut up and used for fish bait.

The giant squids. Fishermen used to return from their voyages with tales of sea serpents and monsters. One story told of a monster squid called the "kraken." It was supposed to be able to sink large ships and eat their crews.

No one took these squid stories very seriously. But finally giant squids

were discovered and measured by scientists. Some of them were 60 feet long. Perhaps they even grow to be larger. Of course, this is not large enough to sink ships. And there is no record that a squid ever ate a man. But there is no doubt about one thing. Giant squid exist.

These giant squid are rarely seen. This is because they live deep down in the sea. They seldom come close to the surface. But there may actually be a good many of them in deep waters. Whalers keep finding pieces of giant squid in the stomachs of sperm whales. Sperm whales are great divers. It seems that they often feed on the giant squid.

The fact that this big squid went undiscovered for so long shows how little we know about the deep sea. Divers can now go down hundreds of feet, but much of the open sea is two or three miles deep. This deep sea covers about two thirds of the earth and is mostly unexplored. We have better maps of the moon than we have of the sea bottom. Scientists are now developing ways to explore this great unknown region.

William Beebe, the Piccards, and Jacques Yves-Cousteau were important pioneers in undersea exploration. Now there are many groups working on the problem, including the French Navy and the United States Navy. Two men actually went down seven miles to the deepest spot on the ocean floor.

A successful phylum. Can you see why the mollusks are a successful phylum? Long ago the first mollusks must have been much alike – something like a flat-shelled snail. Then different groups of them began to live under different conditions. Natural selection brought change in these groups. Over the ages each group of mollusks has become better and better adapted to its way of life.

Animals that hunt for a living must be swift and quick to react. They must have good sense organs. A shell would weigh them down. The octopus class of mollusks fits this hunter description. Animals that wait for food to come to them can use a heavy shell. A body wrapped in a shell is well protected. The clam class fits this description. The clams have even lost their heads. A head, with its collection of sense organs, is very useful to an animal that moves around. The original mollusks had heads. So do the snails and squids, but a filter feeder like a clam does not.

The snails are in between the clam class and the octopus class in their way of life. They must move about to find food, but their rate of ten feet an hour is fast enough. Their kind of food does not run away. They carry a medium-weight shell with them to hide in when danger comes. So, you see, the different classes of mollusks are the result of adaptation to different ways of life. The mollusks have become numerous because they can live in so many different environments.

Many mollusks are useful to people. Clams, oysters, scallops, snails, octopuses, and squids are all eaten by man. If you live far from the sea, oysters are probably the only mollusks you have ever eaten. They are commonly shipped inland and are sometimes canned. Many oysters are grown in shallow bays by a kind of under-

water farming. The oysterman prepares a bed of broken tile, scrap metal, or old shells for the young oysters to grow on. Then, when the oysters are big enough, he sends them to market.

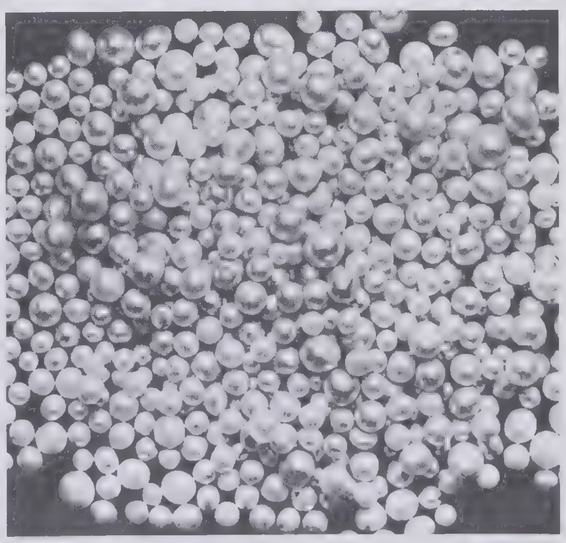
Man has always used the shells of mollusks. Primitive man used them for dishes and spoons. A sharp-edged shell could cut his hair. The two halves of a clam shell were used as tweezers for pulling out whiskers. Beads and other decorations were made of whole shells and pieces of shell. In parts of Africa and in the South Pacific, certain shells were used as money. Mother-of-pearl is still used in some decorations and in inlays. It is simply polished pieces of shell. You may have seen it on knife handles or as inlay on musical instruments.

Shells are also used to make buttons. The common white pearl buttons used on men's shirts are made of shell. Both freshwater clams and the pearl oyster shells are used. After button blanks have been drilled out, the rest of the shell is broken up and sold to farmers. Chickens eat this "oyster shell." The hen's body uses the lime in shells to make eggshells.

Natural pearls are made by mollusks. Because of their beauty they are used as jewelry. Any mollusk that has a shell can make a pearl. A pearl forms around some foreign object, usually a parasitic worm, which gets inside the flesh of the mollusk. On its way into the mollusk, the worm may pass through the mantle, and some of its shell-forming cells are dragged deep into the flesh of the mollusk. There these cells multiply and go right on producing shell. They coat the parasite with this shell material. The result is a pearl. Year by year the

Fig. 30-7. Oyster fishing. Oysters are dug from special beds planted in the shallow waters along the coast. They are hauled by means of stiff nets into the fishing boats which then bring them to market. (Standard Oil Co. of New Jersey)

Fig. 30-8. Pearls are used in jewelry because of their great beauty. How are they formed? (Phillip Gendreau)



pearl becomes bigger as more layers are added to it. If the worm or other object has a regular shape, the pearl has a regular shape too, and is valuable for use as jewelry. Parasitic worms often form cysts inside mollusks. Since cysts are usually round, the pearls around them become spheres. Pearl formation is actually an unusual event. Only one oyster in a thousand is likely to contain one.

Pearls are made of the same material as shell, but we cannot make a pearl by polishing a piece of shell. It must have the natural surface produced by the mollusk. This surface looks like the lining of the shell. If the shell lining is beautiful, then that mollusk can make a beautiful pearl. The shell of the oyster we eat has a dull, gray lining. So you will not find riches in your oyster stew.

A few gem pearls are found in freshwater clams. The Florida conch makes pink pearls. But most of the gem pearls you see come from the pearl oyster. The value of gem pearls depends on size, shape, and color. Black pearls are rare and bring a good price. Rose-colored and steel-blue pearls from freshwater clams are also in demand. One pearl that weighed 14 pounds was found in a giant clam but it did not have a good shape.

The Japanese use a way of forcing pearl oysters to make pearls. They take a bead made out of shell and cover it with live mantle cells. It is then thrust into the flesh of a pearl oyster with a pair of long, pointed tweezers. Oysters treated in this way are placed in wire cages and returned to the sea for several years. Pearls form around the beads. They are called *cultured pearls*. They look exactly like natural pearls, but they sell at much lower prices. People will pay more for a pearl with a worm in it than for one with a bead in it!

ACTIVITY

Observing snails. Collect several kinds of living snails. Many snails can be found in any pond, stream, or lake. Pet stores and scientific supply companies sell them. Land snails can be found among the dead, damp leaves in almost any woodland. Slugs may live in woods, gardens, or in many backyards. Look for them under stones and boards.

Place the water snails in aquariums. Watch them crawl along the glass to feed on the algae and bacteria that have collected on it. This cleans the glass. Some water snails have gills in their mantle cavities, but others have lungs. See how these snails come to the surface once in a while and open a pore to take in air. They are animals that get their oxygen from the air. Can you guess where their ancestors lived long ago?

Place the land snails and some lettuce leaves in jars. See how these snails use their file-like tongues to eat holes in the lettuce. Place a land snail on the table and watch it crawl. Touch one of its tentacles lightly. What happens? Can you see its head? Its foot? Where is its mantle cavity? Can you see its breathing pore? What does the snail do if you poke it several times with your finger? Measure the time

it takes each of several snails to crawl one foot across the table top. Get the average. At this rate how far would a snail go in an hour?

CHECK YOUR FACTS

1. How does a freshwater clam get its food? How does it move? How is it protected from enemies?
2. What are some parts of the clam that are also found in other mollusks?
3. How do the young freshwater clams find new places to live? How is this different from what salt-water clams do?
4. In what ways is a snail different from a clam?
5. Compare the squid structure with that of a clam.
6. What sort of food is eaten by snails and squids?
7. How does natural selection explain the differences between the mollusk groups?
8. Name some ways in which mollusks are useful to man.
9. How do pearls form?

CHAPTER 31

Some Arthropods

In many ways the ***arthropods*** *(arthro-* jointed; *pods* - feet*)* are the most successful animals on earth. There are more kinds of them than all other animals. They give man more serious competition than any other animals. They live on land, in the air, in the soil, and in water. The arthropods are the buglike animals. They include the insects, spiders, ticks, crabs, shrimps, centipedes, and many, many, others. You will read about insects in Chapter 32.

The arthropods are segmented like the earthworms. Their internal organs are also like those of earthworms in some ways. Perhaps the segmented worms and the arthropods developed from similar ancestors a long time ago. But today, arthropods are more complex than any of the worms.

The arthropod skeleton. An outstanding characteristic of the arthropods is their skeleton. It is on the outside of the body. It is made of a hard material and has flexible joints. The muscles attach on the inside, and the whole skeleton is very like a suit of armor.

In men and other animals with backbones, the skeleton is inside the body in the form of bones. The muscles attach to the outside of the skeleton. These are the only two kinds of movable skeletons. Which kind is more efficient?

Have you ever seen an ant dragging a caterpillar many times its weight? If you were as strong for your size as the ant is, you could grab a truck by the bumper and drag it up a steep hill. If you could jump as well as a flea, compared with your size, you could leap over a 100-story building.

As you see, the arthropod type of muscle system and skeleton gives these animals great strength. It works very well in the case of small animals. But it does not work well in larger types. You may have seen horror movies in which huge insects or spiders terrified the countryside. Actually, such animals could not exist. Their outer skeletons would be too heavy. Muscles inside their bodies could not move these heavy parts. This is why most arthropods are rather small animals.

There is also a limit to the possible size of animals with inner skeletons, but the limit is much larger. All large land animals and most large water animals have inner skeletons. Of course some animals with inner skeletons are quite small. But they are

larger than most of the arthropods you see on dry land. For an animal the size of a bug, the outer type of skeleton is more efficient.

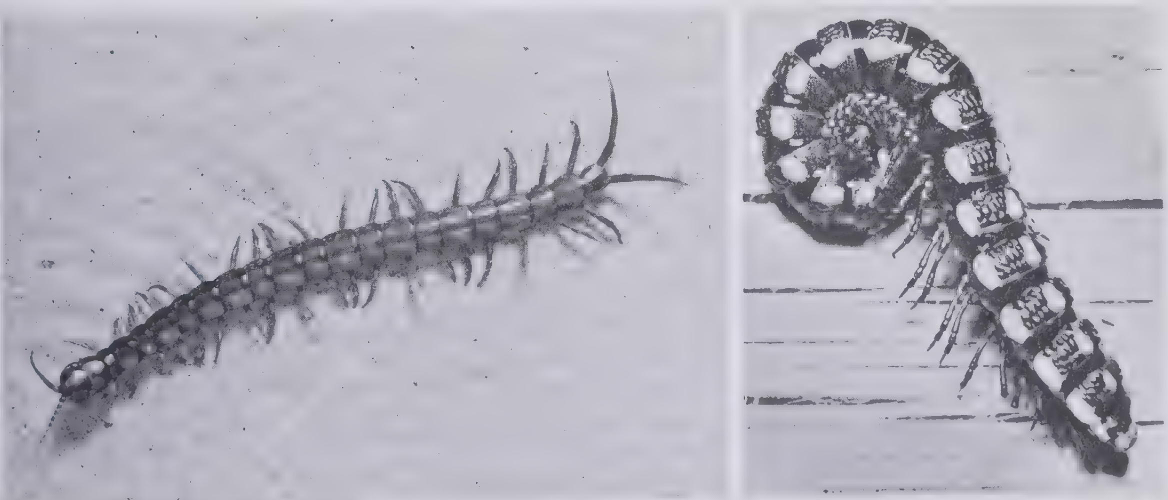
There are some fairly large arthropods. A lobster is an arthropod, and it may grow to a length of three feet. But do not forget that a lobster lives in the water. In water it is easier to move a heavy body about. The largest animals with inner skeletons also live in the water. A blue whale, for instance, may weigh 140 tons.

The success of the arthropods. Small size is not a disadvantage to the arthropods. It is an advantage. We have wiped out the bears, wolves, elk, mountain lions, and other large animals in all of the more settled parts of our country. You may ask why we do not wipe out insect pests. One reason is that their small size makes them difficult to control. They can hide easily, and they do not require much food. They reproduce rapidly. If 99 percent of a species were wiped out, the remaining one percent could replace the loss in a short time.

Suppose all the eggs from one pair of houseflies hatched into houseflies which also reproduced at their normal rate, and this process went on for one summer. The total number of flies descended from the first pair in just one season would completely fill the building of a large high school from floor to ceiling. But luckily insects do not actually increase so rapidly. A good many of them are eaten by their natural enemies. Some die because they do not find the right kind of food. Others are killed by cold, heat, or other unfavorable conditions.

Arthropods have a number of interesting structures. They have jointed legs and other **appendages.** The word appendage is a handy one to know. It means an arm, leg, feeler, wing, or any other part that extends out from the body. Some arthropods have mouth parts adapted for chewing. Others have mouth parts adapted for sucking up juices. All of them have

Fig. 31-1. A centipede (left) and a millepede (right). How can you tell them apart? (Pinney/Monkmeyer; Walter Dawn)



fairly well-developed nervous systems. They are able to carry out complicated activities.

Some classes of arthropods. Two arthropod classes are the ***centipedes*** and the ***millepedes.*** Both of these types have long segmented bodies. Both have large numbers of legs. The centipedes have one pair of legs on most body segments. Millepedes have two pairs. The number of legs varies a great deal, but most centipedes have about 40, and most millepedes about 100. A centipede and a millepede are shown in Figure 31-1.

Both centipedes and millepedes are commonly found in the ground or in almost any dark, damp place. Millepedes eat decaying plant materials. Even with all of their legs, they generally move slowly. Centipedes use pincerlike poison jaws to catch insects or other small animals. The poison from the jaws helps to overcome the victims. Common small centipedes are harmless to man. But some tropical centipedes are as much as 12 inches long. These big ones can give people painful bites.

The crayfish class. The ***crustaceans*** (kruhs-*tay*-shuns) include crabs, lobsters, shrimps, prawns, and crayfish. These are well-known animals because many of them are good to eat. Freshwater ***crayfish*** have always been favorite animals for study in biology classes. A crayfish does not have the wormlike shape of a centipede. Its segments and appendages have become specialized to do different jobs. At the front end of the body the segments are all grown together, so that the head-chest region does not even look segmented. In the rear part of the body the segments show clearly. They form the ***abdomen*** (ab-*doh*-men). This is not a tail, for the intestine runs through its whole length.

A crayfish has 19 pairs of appendages. There are 2 pairs of feelers, 6 pairs of mouthparts, 5 pairs of legs, 5 small pairs of appendages under the abdomen, and a pair of tail fins.

The mouthparts are handy tools for holding food, cutting it up, grinding it, and pushing it into the mouth. The first pair of legs bear large powerful pincers. The appendages under the abdomen are used in slow, forward

Fig. 31-2. A lobster (left) and a crab (right). How are they alike and how do they differ? (Douglas P. Wilson, F.R.P.S. for both)

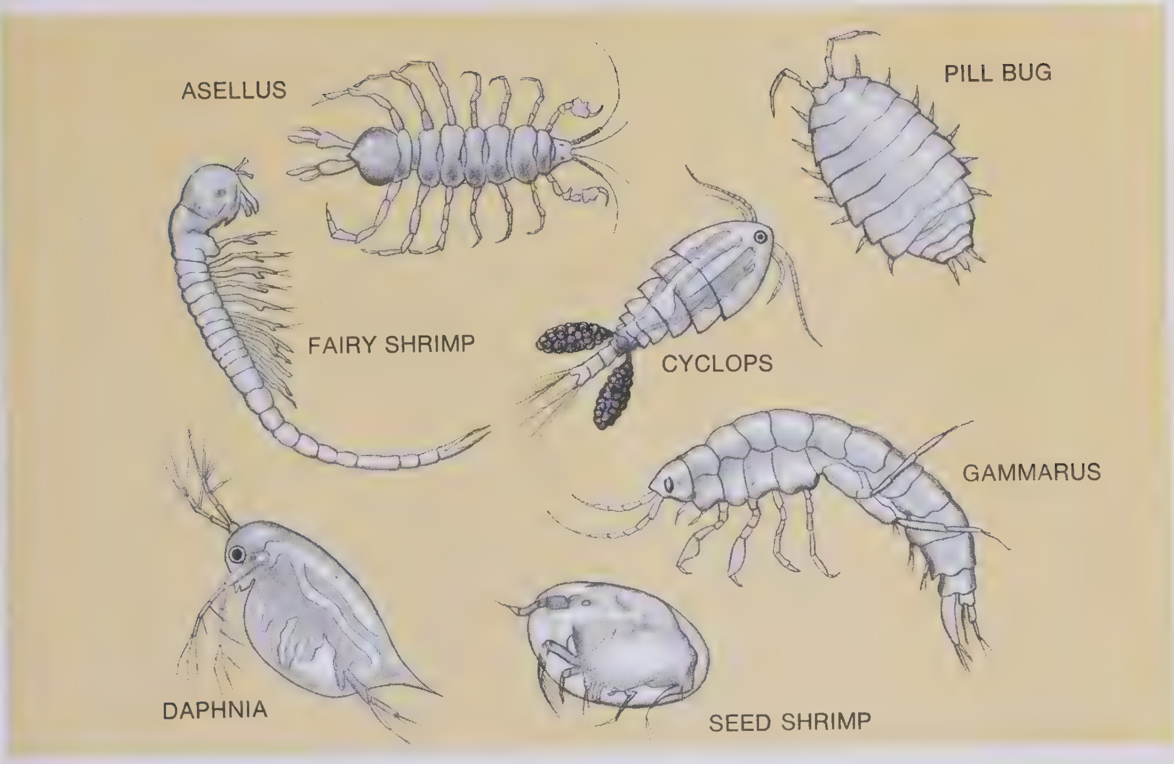


Fig. 31-3. This drawing shows a few of the many kinds of small crustaceans. Some, like *Cyclops*, are so small you can hardly see them without a microscope. Do these tiny animals have any value?

swimming, for sending water through the gills, and for carrying the eggs until they hatch. There are gills hidden in cavities on each side of the body.

Crayfish live in lakes, ponds, and streams. By day, they hide under rocks and logs. At night they come out and hunt. A crayfish eats tender plants and any live or dead animal material it can find. The big claws on the front legs are used to catch food and also for defense. If a crayfish is frightened, it swims backward by flipping the abdomen underneath the body.

If the pond where crayfish live dries up, they do not die. The water table is still near the surface, and they dig down to it. Each crayfish makes a neat, round hole going nearly straight down. During the day it stays in the water at the bottom, keeping its gills wet. At night it comes out and hunts for food, but it must return to the hole again before its gills dry out.

Lobsters and sea crawfish live in the ocean. They are very similar in structure to crayfish. Crabs are also somewhat similar. They have the same sort of legs and pincers, but their bodies look different. A crab's abdomen is very small and is carried under the chest where it does not show. The crab's body is often flattened so that it looks like a plate with legs.

The most important crustaceans are not the big ones like lobsters and cray-

fish. They are the small ones, which live in very large numbers in fresh water and in the oceans. They are the buglike animals of the sea. Small crustaceans come in many sizes and shapes (see Fig. 31-3). Many are too small to see without a lens. Others are the size of very small insects. Some are two or three inches long. They drift in the open sea. They crawl on seaweed. They live on the bottom, at various depths. Some eat algae, and some eat other crustaceans. Some are parasites. The ones that eat the tiny, free-drifting forms of algae are the most important. They are the main plant eaters of the open sea. They are the first step in most of the food chains. Even the biggest whales eat them. These huge mammals swim through the sea with their mouths open, like big vacuum cleaners, taking in millions of small crustaceans. Crustaceans are also eaten by many fish.

The spider class. The arachnids or spider class of arthropods includes not only the *spiders* but also the *ticks* and *scorpions*. All of these have eight legs. This helps you to tell them from the insects. ***Ticks*** are small spider-like types which suck the blood of larger animals. They sometimes carry serious diseases. Texas fever in cattle and spotted fever in man are carried by ticks.

Scorpions live in warm regions, including the southern United States. They look a little like crayfish, but the two are not closely related. They have a long, segmented body, with a slender abdomen. There is a stinger on the end of this abdomen (Fig. 31-4). One of the two pairs of mouthparts is large, with pincers on the ends. These are used to take hold of insects. The abdomen whips over and stings the victim. Then the scorpion eats.

Scorpions hunt at night and hide in dark places during the day. The dark place might be a shoe, a shirtsleeve, or a bed. People in scorpion country learn to shake out their clothes every morning before dressing. A scorpion sting is painful but usually not serious. However, in southern Arizona there are small, straw-colored scorpions that are very poisonous. Their stings have killed children less than three years old. Hospitals in that area keep a serum on hand for treatment of scorpion stings.

Many people think of spiders as harmful and dangerous animals. But spiders have their uses. They are important in the balance of nature. They keep certain insects in check. This is to our advantage because insects are our chief competitors.

People do get bitten by spiders now and then. Most of the bites, however, are not very serious. They just cause itching and swelling. But one spider which is found in North America is really dangerous. It is the famous black widow and it is the female that you have to look out for. She is a "widow" because she kills the male as soon as they have mated. People have been known to die from black widow spider bites, but most victims recover.

Spiders have two body parts – a combined head and chest region in front and an abdomen behind. The eight legs are on the chest. The jaws are armed with a pair of poison fangs. These are used to kill insects. A spider sucks liquids from the body of the insect. It does not eat the hard parts.

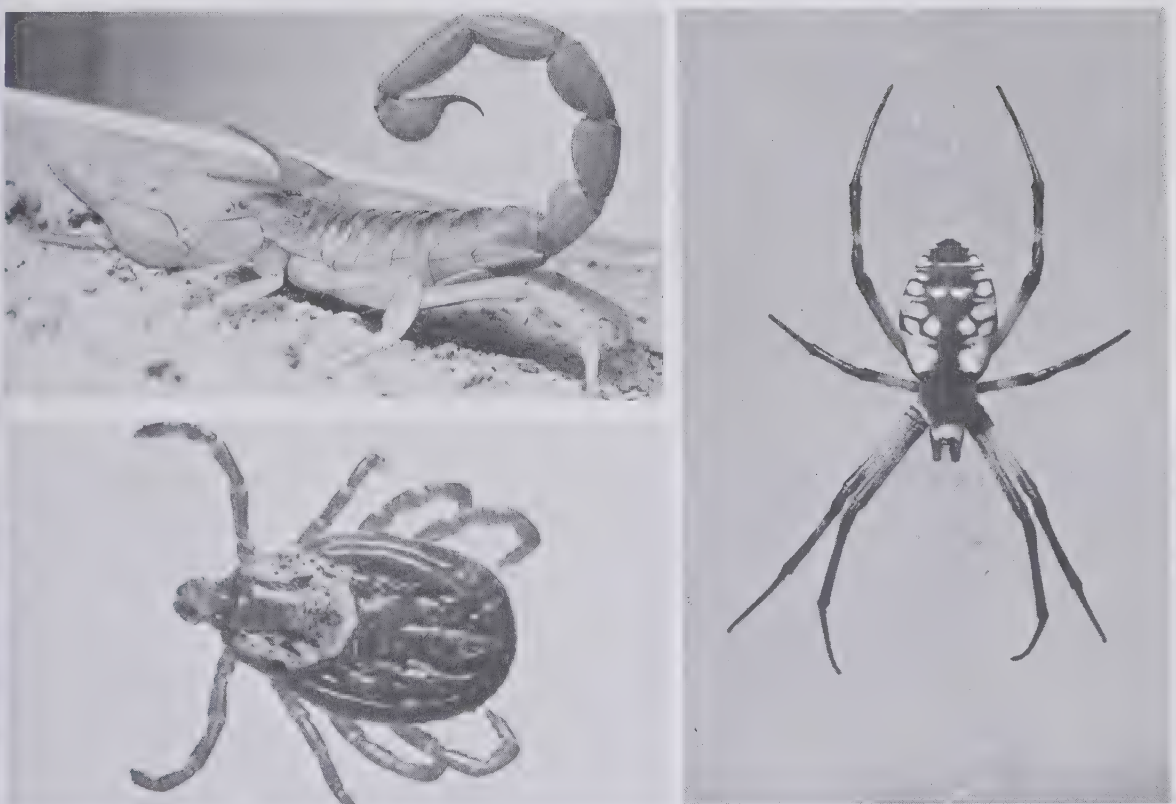


Fig. 31-4. Various members of the arachnid group. Here you see a scorpion, a common tick, and the ordinary orange garden spider. (Paul Knipping; Hugh Spencer; Jack Dermid)

Spiders catch insects in many ways. Some run after them. Some creep close and then jump. Some hide in holes and run out to catch passing insects. Many spin webs to use as traps. The web is made of silk which comes from glands at the back of the abdomen.

ACTIVITY

Observing crayfish. In your study of pond cultures and of feeding **Hydra,** you have probably seen small crustaceans. Now we shall study a large one.

1. Get a live crayfish. Place it on the table top. You can hold a crayfish by gripping its chest between your thumb and forefinger. It cannot reach far enough back to pinch you. Does it try to pinch? Poke at it gently with a pencil eraser as it rests on the table top. Does it defend itself? Watch it walk. Place it in a tank of water and poke at it there. Does it fight or try to get away? How?

When a crayfish is resting quietly in the tank drop a worm or a piece of meat in front of it. Watch how

it uses its pincers and mouthparts to place the food into its mouth. Always keep live crayfish in shallow water (one or two inches deep). They will die in deeper water. Can you guess why?

2. Examine the outside structure of a fresh or preserved crayfish. Feel the armor-like outer skeleton. Count the feelers, mouthparts, and legs. Examine the small appendages under the abdomen. Use scissors to trim the strong plate off the side of the chest of a dead specimen. This exposes the gill cavity. These white feathery structures are the gills. What do they do?

CHECK YOUR FACTS

1. **If you found an animal which you had never seen before, how could you tell that it was an arthropod?**
2. **How is the small size of arthropods an advantage to them?**
3. **What are some advantages and disadvantages of an outside skeleton?**
4. **How can you tell a centipede from a millepede? What does each of these animals eat?**
5. **Describe the structure of a crayfish?**
6. **What does a crayfish do when its pond dries up?**
7. **How is a crab different from a crayfish?**
8. **What makes the crustaceans such an important group in the sea?**
9. **What food is eaten by ticks? Why are they dangerous?**
10. **How do scorpions get their food? Are they dangerous to man?**
11. **What is the main importance of spiders? How do they get their food? How do they eat it?**

CHAPTER 32

More Arthropods—The Insects

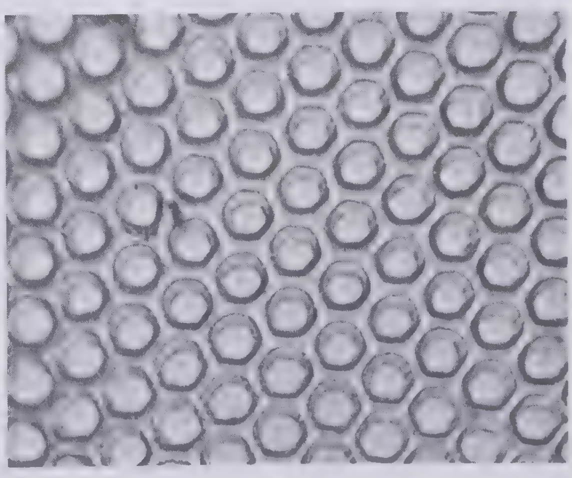
Insects are the common arthropods on land, just as crustaceans are the common ones in the sea. You can recognize an insect by its six legs and its three body parts—*head, chest (thorax)*, and *abdomen.* Most insects also have one or two pairs of wings. They were the first winged animals. Fossils show us that insects were already flying far back in the Coal Age, millions of year ago.

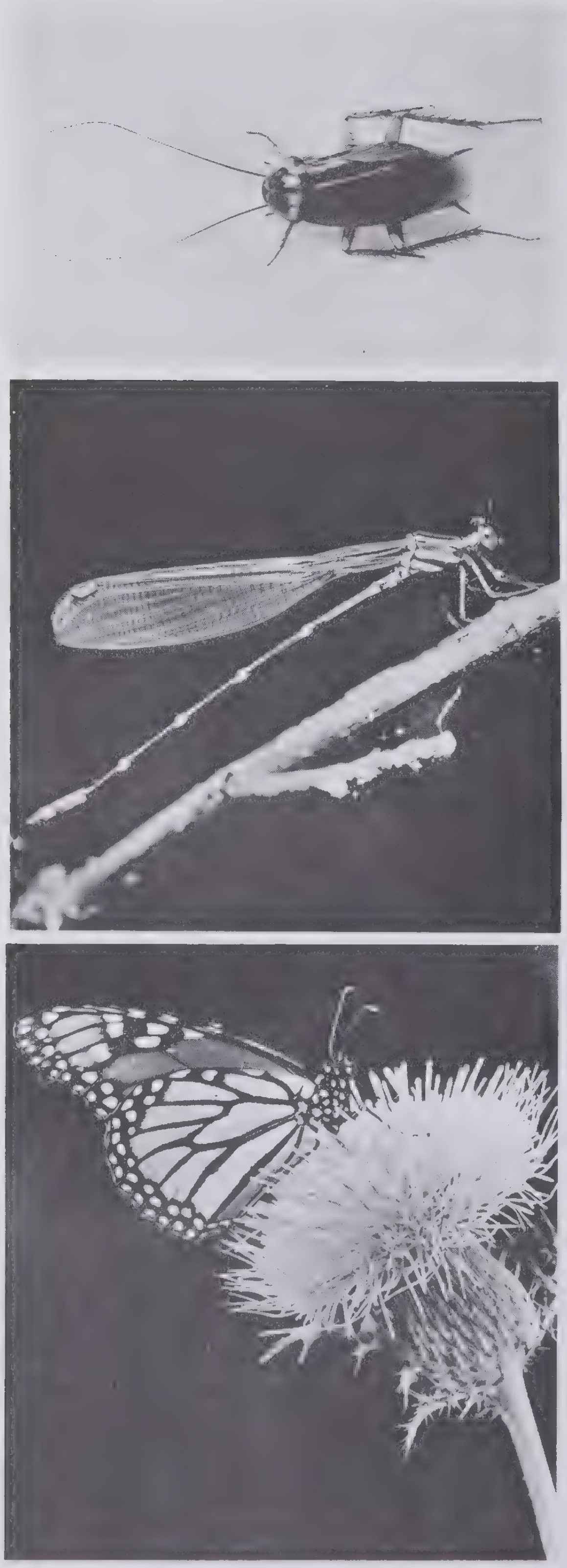
Structures of insects. We shall use a grasshopper as an example of an insect. If you can catch one, look at it through a magnifying lens. Otherwise, study a preserved specimen or use Figure 32-1. The head has two long feelers. Some insects feel with these. Others may detect sounds with them. Still others seem to smell or taste with their feelers.

A grasshopper has two large eyes on its head. These eyes are not like ours. They are made up of a very large number of small eye units packed together. Eyes like these are called ***compound eyes.*** They are the same kind of eyes crayfish and water fleas have. Figure 32-2 shows a close-up of a grasshopper's eye. Note the many small eye

Fig. 32-1. A grasshopper. (Walter Dawn)

Fig. 32-2. The compound eye of a grasshopper. Note the many small units that make up the eye. (Hugh Spencer from National Audubon Society)





units. A grasshopper also has three very small *simple eyes.*

The mouth of a grasshopper has upper and lower lips, two pairs of jaws, and a tongue-like structure. With these mouthparts the grasshopper is able to bite off and chew bits of plant leaves. Many other insects have chewing types of mouth parts. Others have mouth parts that are modified in various ways.

In butterflies the mouthparts form a long hollow tube that is used for drinking nectar from flowers. In mosquitoes the mouth parts include a hollow tube with which they suck blood.

Examine the grasshopper's legs. See how they are jointed for efficient movement. There are hooks near the ends of the legs, used for hanging on to things. Most insect legs are of this general structure, but of course all insects do not jump like the grasshopper. The large back legs of grasshoppers are modified for jumping. Other insects have legs modified for running, digging, swimming, and catching other insects.

A grasshopper folds its wings over the top of the abdomen. The front wings are narrow and leathery. The wide back wings are thin, like cellophane. They fold up under the front wings. When the grasshopper flies, the wings unfold and reach out sideways. Some grasshoppers fly well. Others use their wings just to help them jump a little farther.

A grasshopper gets oxygen through pores in its side. There are pairs of

Fig. 32-3. Various orders of insects. From top to bottom: cockroach (grasshopper order); damsel fly (dragonfly order); monarch butterfly (moth and butterfly order) (USDA Photo/Walter Dawn/Lynwood M. Chace)

these pores on ten of the grasshopper's segments. They connect with branching tubes that carry air to all parts of the body.

Female grasshoppers lay their eggs in the surface of the soil. They do this in the fall of the year. When an egg hatches in the spring, the young grasshopper is quite small. It has no wings or sex organs. But it looks and acts just like an adult grasshopper. It is called a ***nymph*** *(nimf)*. The nymph feeds and grows. After a while it sheds its outer skeleton. This growth and shedding of the outer skeleton keeps up until an adult is produced.

Kinds of insects. There are about 25 orders of insects. The following list gives seven of the most common ones:

1. *The grasshopper order.* Besides the grasshoppers this order includes crickets, walking sticks, cockroaches, and katydids. Grasshoppers and crickets are very destructive insects. They eat about ten percent of our grain and pasture crops before they are harvested. The locust plagues that you hear about in Africa and Asia are simply swarms of flying grasshoppers.

2. *The dragonfly order.* These insects are often called "darning needles." They are beautiful, long-bodied insects, with marvelous flying ability. Like grasshoppers they have two pairs of wings. They feed upon other in-

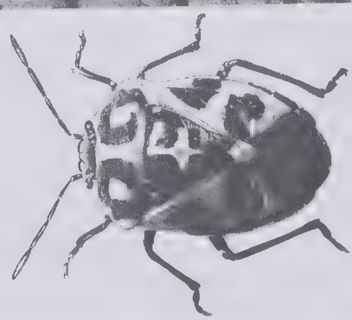


Fig. 32-3. Various orders of insects. From top to bottom: soldier beetle (beetle order); crane fly (fly-mosquito order); harlequin bug (bug order); wasp (bee order). (Walter Dawn/Walter Dawn/USDA Photo/Treat Davidson from National Audubon Society)

sects, including mosquitoes. Young dragonflies live underwater, where they eat mosquito larvae and other insects.

3. *The bug order.* The word *bug* is used by biologists for the insects of this one order only. These insects have sucking beaks, which they use for eating liquid foods. Stinkbugs, squash bugs, chinch bugs, and many others stick their beaks into plants and suck the plant juices. Assassin bugs attack other insects. Bedbugs suck human blood. You can recognize these insects by their peculiar wings. The upper wings are thick in front but thin at the tips. They fold to form a crisscross pattern on the back.

4. *The butterflies and moths.* These large-winged insects are often very beautiful. Some adult moths have no mouths. Other moths and all butterflies have long tubes through which they suck nectar. They do some pollinating of flowers. The larvae of this order are caterpillars. These are wormlike forms with chewing mouthparts. Often they are very destructive, since their food may be the leaves of useful plants. They eat steadily and grow rapidly. Finally, they go into a resting stage, in which they do not look like either caterpillars or adults. This resting form is called a ***pupa*** *(pyoo-*pa*)*. In moths the pupa is often surrounded by a case called a *cocoon.*

During the resting stage the body of the animal is completely reorganized. Then the outer covering splits, and the adult insect crawls out. It is as if a tractor had been changed into an airplane. No wonder a resting stage is needed. The first three orders of insects in our list do not change like this. A young grasshopper looks like a grasshopper. It does not look like a worm. There is no resting stage in the grasshopper's development.

5. *The beetles.* These are the most heavily armored of the insects. Their outside skeleton is very strong, and the front wings are heavy shields which cover the abdomen. When a beetle flies, these front wings are raised, and the thin back wings unfold to do the flying. Beetles have chewing mouthparts, much like the grasshoppers.

This is a very large order of insects. It includes useful types, such as the ladybird beetles, the tiger beetles, and the ground beetles. These feed upon other insects. Many other beetles are serious pests. They feed upon all kinds of plants, including some that are useful to man. The larvae of beetles are sometimes called grubs.

6. *The fly and mosquito order.* This order includes a few useful types, such as the robber flies, which eat other insects. But the order also includes some of our worst pests. They have sucking mouthparts, and many of them feed on blood. Some of them carry disease germs from one host to another. Malaria, yellow fever, sleeping sickness, and several other deadly diseases of man are carried either by flies or mosquitoes.

Houseflies are well-known members of this group. They do not bite, but lap up free liquids. Their young live in piles of animal manure . The adult flies walk about on our foods. Their bodies are covered with short hairs and bristles which collect dirt and germs wherever the flies go. Naturally, the flies leave dirt and germs on food.

You can recognize members of the fly order by the fact that they have

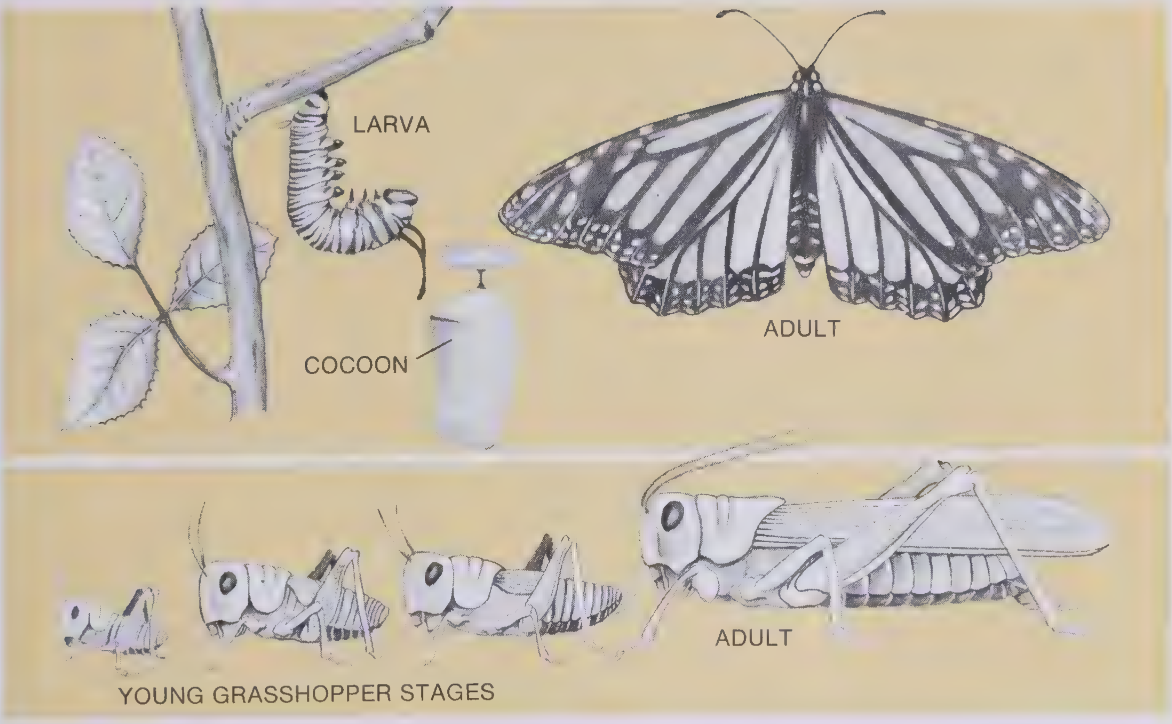


Fig. 32-4. Top: the life cycle of a butterfly, which shows its development from larva to adult and bottom: the life cycle of a grasshopper. How do the two types of development differ?

only two wings. Their larvae are usually called maggots.

7. *The ant and bee order.* This order includes bees, wasps, and ants. Bees, as you know, are the most useful of all insects in pollinating flowers. A great many plants could not reproduce if there were no bees.

One of the most interesting things about this order is that many of its species live in well-organized groups or societies. They are known as *social insects*. A beehive, a hornets' nest, or an anthill is like a city with many citizens living in it. A honeybee colony usually has just one egg-laying female, the queen. Most of the others are workers, which are females that never reproduce. A few males, called drones, may be present. The workers gather food, care for the queen bee, raise the young, and defend the group against enemies. Ants have the most complex organization of all. They may have several kinds of workers which do different kinds of jobs.

Controlling harmful insects. As you have seen, some insects are useful to man, but many of them give us serious competition. They eat our food supply. Termites and clothes moths eat our building materials and clothing. Mosquitoes and lice feed directly on man and carry diseases.

Insect numbers are kept down mainly by their natural enemies. These include disease germs, centipedes, scorpions, spiders, frogs, lizards, shrews, birds, and bats. Also impor-

tant are the insects that eat other insects. In spite of all these enemies, insects still manage to give us trouble.

If we wish to get rid of flies or mosquitoes in a neighborhood, we may attack them where they breed. Manure and garbage are food for fly maggots. Destroying manure piles and burying or burning garbage gets rid of most flies. Mosquito larvae live in water. Pools and swamps can be drained or planted with small, insect eating fish.

We can encourage the natural enemies of insects. On farmlands which have some trees and shrubs along the fences, there is less insect damage to crops. Birds nest in the trees and feed upon grasshoppers and other insects in the fields nearby. Not many birds can live in country where nothing but crop plants are allowed to grow.

We have imported enemies of some insect pests. New species of ladybird beetles and of ground beetles have been brought into the country because they eat certain kinds of undesirable insects.

In the southern United States there was a very serious insect pest called the *screw worm fly*. This fly laid its eggs in any wounds it could find on large mammals. The larvae grew in the flesh of the mammal, often causing its death. A great many cattle were lost because the flies laid eggs on the navels of new-born calves.

The fly now has been very nearly eliminated in the southern states. This was done by raising and releasing many thousands of male screw worm flies. Before they were released these males were sterilized by exposing them to X rays. They produced semen which contained no sperms. These males mated with normal, wild females which then laid unfertilized eggs. These eggs never hatched. The sterile males were produced in very great numbers. There were more of them than there were of the wild males, so most females mated with sterile males. Sterile males were released each year until no new larvae were being produced.

Biologists are now experimenting to see if this method can be used to kill off other pests. They are also studying the use of odors in controlling insects. Many male insects seem to be attracted to the females by their odor. Apparently a male moth can smell a female moth a mile away. The idea is to use such odors to attract the males into traps. A different odor would, of course, be necessary for each species.

Such methods as the use of natural enemies, or sterile males, or attractive odors are called biological controls. When they can be used, these biological controls are far better than poisons. Insecticides are useful in

Fig. 32-5. These fruit trees are being sprayed to prevent damage from both insects and fungi. Why is it necessary to choose the chemicals for such spraying very carefully? (Dow Chemical Co.)

limited areas like orchards and truck gardens, but they have many drawbacks, as you read in Chapter 17.

Biological controls hit the particular pest species without destroying other members of the community. The development of biological controls is a rather new field of science. Perhaps the time will come when we can always destroy just the pests without hurting other forms of life.

ACTIVITY

Observing insects. If you have followed the directions on page 279 you have already studied one insect—the grasshopper. Now compare it with other types. Either collect your own specimens or use insects from your school collection. Try to find insects that are members of each of the seven orders listed on pages 281-283. You can make a table of your observations. See how the insects differ in type of mouthparts, type of wings, antennae, body shape, and type of legs. What structures are adaptations to the way each species lives?

Keeping living insects. Keep some insects in a cage. Use a cage already present in your school equipment or make one yourself. Screen wire can be bent around to form a box. You can lace it together with wire. In your cage place some leaves and twigs and a dish of water. Crickets are good insects to keep. You can catch your own in the fall. During the winter they can be bought from some scientific supply companies. Feed them pieces of vegetables and fruits. Watch how their mouthparts work when they feed.

Place the cage in a cool place for a day. Then put it in a warm place for a day. Can you see any difference in the way the insects behave at different temperatures? If the crickets are doing any singing, notice any changes in the rate at which they chirp at different temperatures. Why would a cold-blooded animal change its rate of activity at different temperatures?

CHECK YOUR FACTS

1. **How can you recognize an insect?**
2. **List as many of the insect appendages as you can (there are eighteen if you get them all).**
3. **How is the insect eye different from ours?**
4. **How do insects get oxygen?**
5. **Explain the two kinds of life histories found in insects. Give examples of each.**
6. **Name some examples of each of the seven orders of insects listed in this chapter. Are these all of the insect orders?**
7. **Name four ways in which we try to control insect pests.**

8. **How are most insects prevented from becoming too numerous?**
9. **Name some ways in which insects are useful and some ways in which they are harmful.**

CHAPTER 33

The Starfish

The starfishes and their relatives form a peculiar phylum of animals. Nearly all of them have some kinds of spines on their bodies. They also have organs that are found in no other animals. The starfishes you see along ocean beaches are members of this group.

Starfishes and their relatives have amazing ability to grow new parts. You can cut off an arm and the starfish will soon grow a new one. You can cut the animal in two and it will soon become two starfishes!

Structure of the starfish. A starfish has no head. It has a circle of arms that come together at the center of the body. At this center there is a stomach which opens through a small mouth on the underside. The skeleton of a starfish is made of many small plates of hard lime. These plates are connected by softer material so that the whole animal is flexible. There are many short *spines* all over the body. All parts of the skeleton, even the spines, are covered by a thin, fleshy layer. Figure 33-1 shows how the arms form a star-shaped body.

Inside the animal is a body cavity that extends out into the arms. The liquid in this cavity is mostly sea-

Fig. 33-1. The common starfish feeds mostly on clams, oysters, and small fish. The brittle star with its long, slender arms is a scavenger and eats bits of decaying matter on the ocean floor. (L. Hugh Newman/R. H. Noailles)

Fig. 33-2. A starfish eating a small fish. The starfish's tube feet have moved the fish toward the center of its body and its mouth will soon open to take in the food. (Kurt Severin)

water. This liquid carries dissolved foods and oxygen around the body. The liquid is kept in motion by cilia that line the body cavity. On the upper surface between the spines are many little bulges. They are made of thin membranes. Oxygen molecules pass through the membranes into the body cavity of the starfish.

A starfish moves on ***tube feet.*** There are hundreds of these little flexible tubes lined up in the grooves on the underside of each arm. The outer end of each tube foot acts like a suction cup. The tube feet are connected with a system of water canals that are in the body cavity. When water is pumped into these hollow tube feet, they reach out. Withdrawing the water pulls them in. With hundreds of tube feet pulling at any one time, the starfish is able to move along.

The common starfish eats clams and oysters. It crawls over the top of a clam, clamps on to both sides of the shell with its tube feet, and begins to pull. Of course the clam tries to hold its shell shut, but finally the steady pull of the tube feet wins out. The shell opens.

The mouth of a starfish is much too small to swallow a clam. It cannot bite off pieces either. A starfish meets this problem in a most unusual way. It turns its stomach inside out and then pushes it out through its mouth. The thin-walled stomach slides in through the open shell of the clam and clamps against the soft flesh. Digestive juices that are produced by the stomach lining then kill and digest the clam. When the dissolved food has been absorbed, the starfish pulls in its stomach and moves away on its tube feet. Starfish also eat any other animal food they find. This includes dead fish along the bottom.

Animals related to the starfishes. Other members of the starfish phylum include ***basket stars, sea urchins, sea lilies,*** and ***sea cucumbers.*** Sea lilies are filter feeders. They grow attached to the bottom by long stalks and reach their feathery arms into the water to catch food.

Sea urchins are globe-shaped and covered with spines (Fig. 33-3). They reach downward with a five-pointed set of jaws to pull in bits of food. Sand dollars are similar, but not so spiny, and very flat (Fig. 33-3). They look a little like silver dollars. Sea cucumbers are long and soft and actually look something like cucumbers (Fig. 33-3).

In some countries they are gathered to use in soups and other dishes. The fleshy body wall is eaten. In sea cucumbers this body wall contains only a few plates.

If a fish or crab attacks a sea cucumber, it gets a surprise. The sea cucumber contracts its body wall very forcefully. This breaks loose its intestines and blows them out into the face of the attacker. They stick to it. By the time the enemy has rubbed the sticky mass off its face the sea cucumber has moved away. In time it will grow a new set of inner parts.

Importance of the starfish. These animals are extremely numerous in the sea. They just about cover the bottom in some places. Some of them live in shallow water. Other species are found at great depths. Any group so large in numbers must play an important part in the food chains of an ocean community.

As far as man is concerned the members of this phylum are of little importance. They live in the sea, and we live on land. Few of them are useful to us. Some people eat sea cucumbers, and dried starfish make good souvenirs. Starfish are a great annoyance to oystermen because one starfish can destroy as many as twelve clams or oysters in a day. In some parts of the world the spines of sea urchins are painful to the feet of bathers.

Strange as it may seem, the starfish

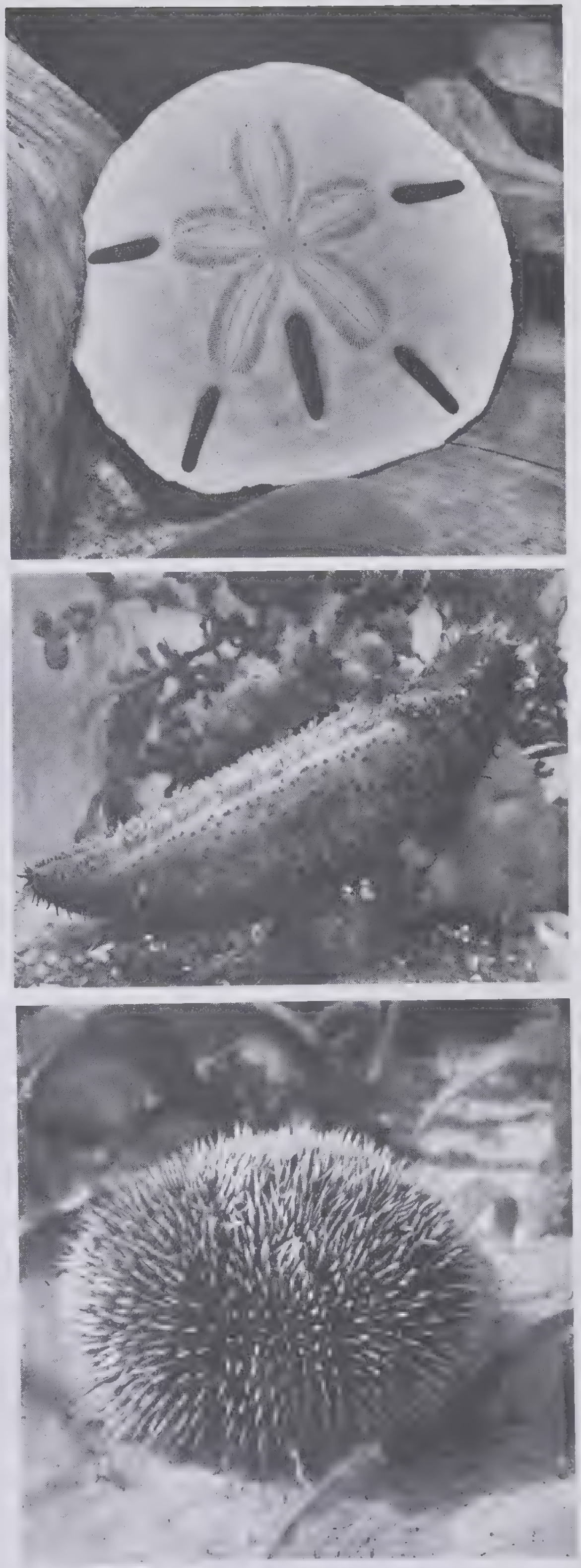


Fig. 33-3. Several members of the starfish phylum. Top: a sand dollar; center: a sea cucumber; bottom: a spiny sea urchin. What structures do all these animals have in common? (Walter Dawn from National Audubon Society/Russ Kinne—Photo Researchers, Inc./Russ Kinne)

phylum is thought to be more closely related to us than any of the other animals we have studied so far. The larvae of the starfish are very similar to the larvae of certain primitive members of our own phylum (the vertebrates). It would appear that you and the starfish come from the same ancestors who lived about 600 million years ago!

ACTIVITY

Observing members of the starfish phylum. Examine all of the specimens of the starfish phylum your school may have. In what ways are they alike? In what ways are they different? If you live near the sea, place live starfish or sea urchins in an aquarium of seawater. Watch how the tube feet carry the animals across the bottom and even up the side of the glass.

CHECK YOUR FACTS

1. **How does a starfish move?**
2. **How does a starfish eat?**
3. **Name some other members of this phylum.**
4. **Of what importance is the starfish phylum?**

CHAPTER 34

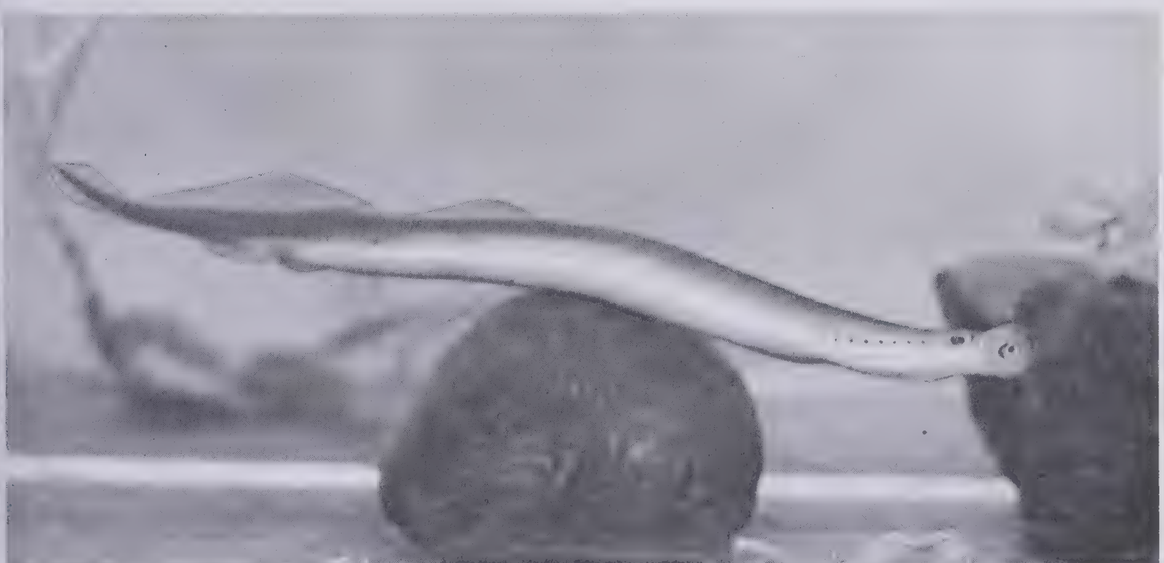
Fish and Amphibians

The ***vertebrates*** are the animals with backbones. They include fish, frogs, lizards, birds, dogs, man, and many others. Animals in this group have highly organized bodies, with all of the ten systems which were described in Chapter 6.

Vertebrates have an inside skeleton moved by complex sets of muscles. Their bodies have a head and trunk and often a neck and tail. A body cavity contains special organs like the stomach, intestines, liver, and heart. The head has eyes, nostrils, and a mouth. There are usually two pairs of movable appendages.

You probably knew all of this already, for these are the large animals you see almost every day. There are three classes of vertebrates that are adapted to life in the water. They are all called *fish*. Then there are four

Fig. 34-1. A lamprey. This is a very ancient type of fish. Notice the separate gills, the sucking mouth with its lack of jaws, and the lack of paired fins. (W. J. C. Murray from Newman's Natural History Photographic Agency)



other classes of vertebrates: *amphibians* (am-*fib*-ee-uns), *reptiles*, *birds*, and *mammals*.

The fishes. A very old and primitive type of fish is the ***lamprey*** *(lam*-pree*)*. There are several species. Lampreys are found in both fresh and saltwater. Lampreys have no jaws and no paired fins (Fig. 34-1). Their skeletons are made of cartilage or gristle instead of bone. They live by attacking other fish. Their mouths are big round, suction funnels bearing teeth which they clamp against the sides of their victims. Then they use their spine-covered tongues to tear away the flesh. They eat the soft parts and blood. Such an attack is very likely to kill the fish. A fish that escapes may have a round scar on its body.

The ***sharks*** are an old and successful group of fish. They also have skeletons made of cartilage. They are equipped with several rows of flat, sharp edged teeth. The sharks are hunters, preying upon other sea animals. Some sharks are fairly small, but others are really large animals. The whale shark is the largest of all fish. It grows to a length of 40 feet or more. Like many whales, it eats by scooping tiny forms of sea life out of the water.

Sharks live mainly in warm seas, but some range quite far north. Most sharks do not attack man, but a few species are really dangerous. Many people have been killed by them.

The skates and rays are also members of the shark class. They have very flat bodies, with the mouth on the under side. They are adapted to feed

Fig. 34-2. A shark. Note how well it is built for swimming very rapidly. How does it use this ability? (Jacana, Paris)

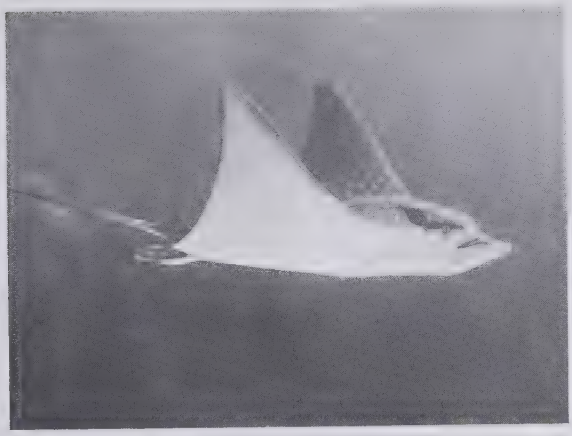


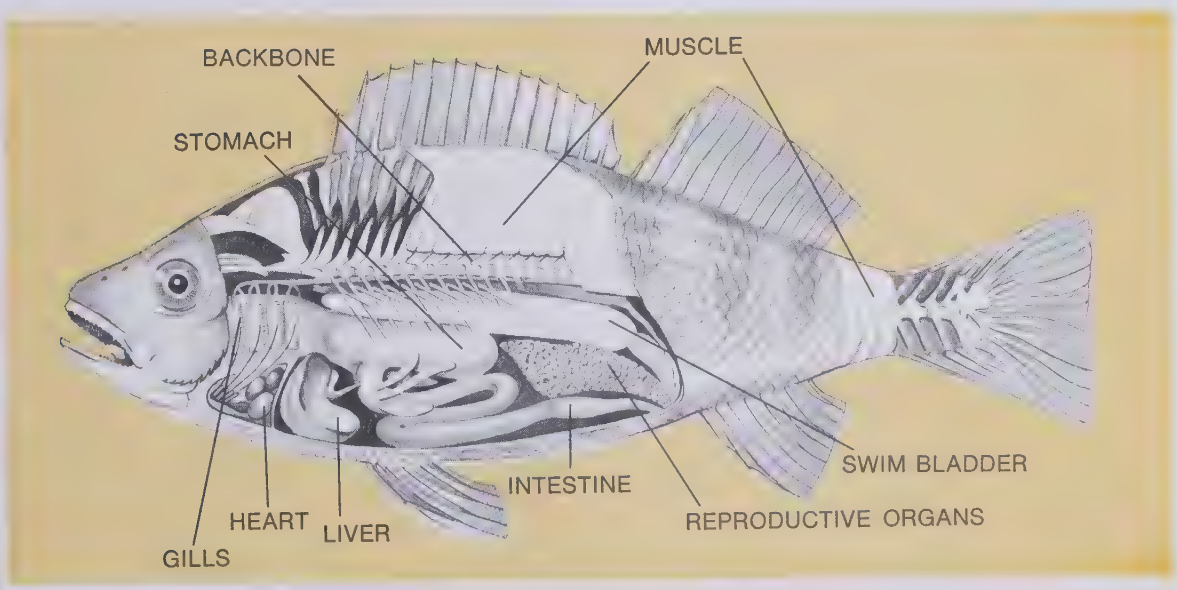
Fig. 34-3. A sting ray. See how it appears to fly through the water. This relative of the shark feeds off the bottom of the sea. Where is its mouth? (Annan Photo Features)

and hide on the bottom. They swim by waving the big triangular fins on the sides of their bodies. This makes them look like they are flying through the water. Their tail is a long whip. Often there is a poisoned spine near the base of this tail. This can give a painful wound to anyone who steps on the fish. At such times it is important to get an antitetanus shot, for these stingers often carry dangerous germs.

The ***bony fishes*** are the ones that we know best. They include perch, bass, pike, cod, mackerel, salmon, and many others. They have skeletons of bone. Most of them have a covering of scales.

Fish get their oxygen by means of gills. The gills are fastened to bony arches along each side of the throat. A gill is divided into many small parts, which gives it a feathery look and provides a great deal of surface area for absorbing oxygen. The outside of a gill is covered with a thin membrane, and the inside contains blood. Dissolved oxygen molecules pass into the blood through this membrane, and carbon dioxide molecules pass out through it. Water passes in through the open mouth of the fish and out through openings in the sides of the throat. This brings a constant supply

Fig. 34-4. The internal structure of a fish. How many of these same parts are found in man?



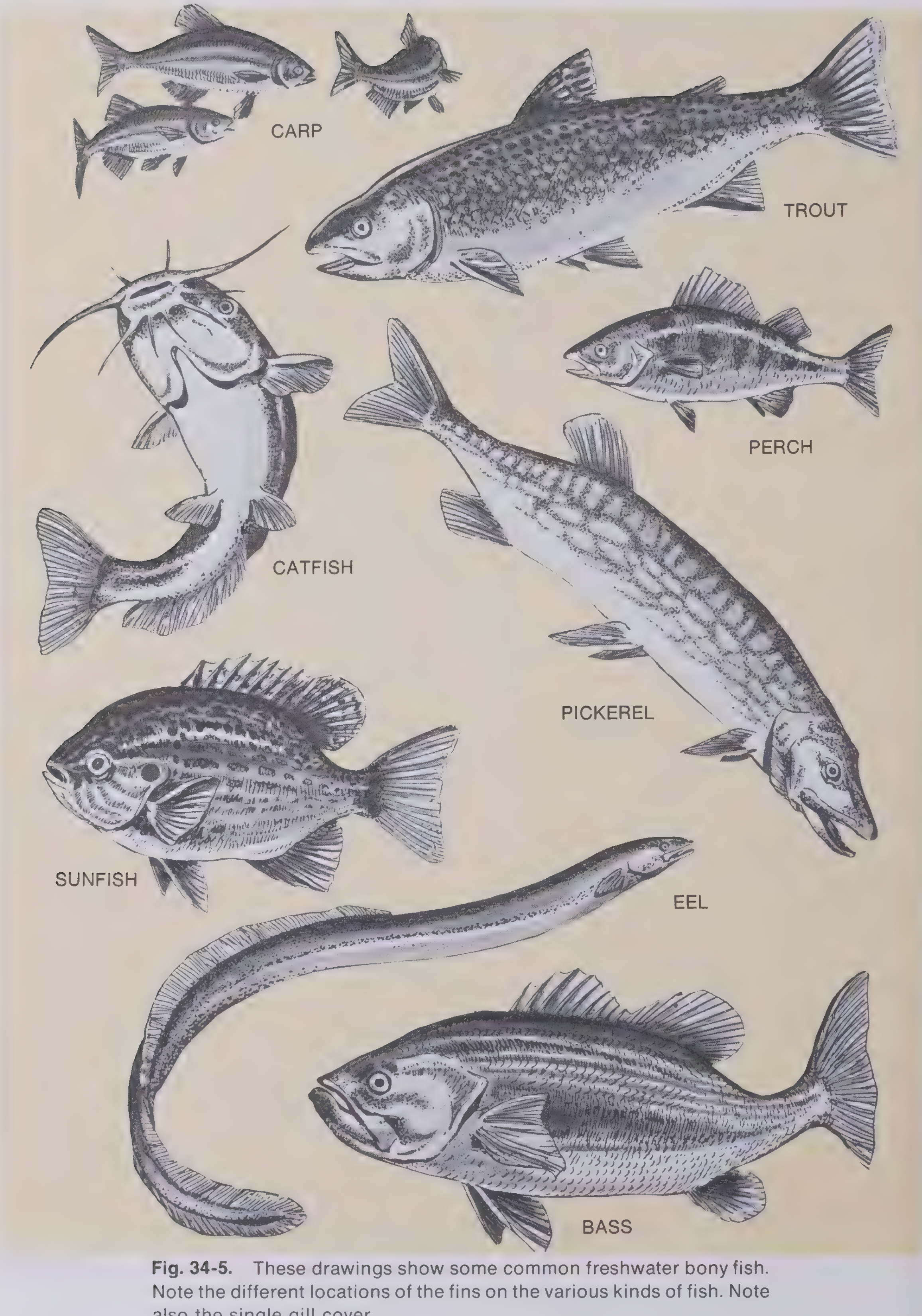


Fig. 34-5. These drawings show some common freshwater bony fish. Note the different locations of the fins on the various kinds of fish. Note also the single gill cover.

of water to the gills. In lampreys and sharks, there is a separate opening in the side of the neck for each gill unit. In the bony fishes there is a single gill cover on each side of the neck over all of the gills. Each gill cover is open along its back edge, where the water goes out.

Fish swim mainly with their tails. The movable pairs of fins, which correspond to our arms and legs, also help in swimming. Some bony fishes have a swim bladder inside the body. This is a gas-filled structure that lightens the fish so that it can drift in the water without sinking. The other inside organs of fish are shown in Figure 34-4. They are much the same in all vertebrates. We shall study the body systems of man later on, so there is no need to go into detail on other vertebrates now.

Importance of fish. Fish are adapted to swim actively against water currents. This means they can go wherever necessary to get food and to avoid enemies. Smaller animals like the free-drifting crustaceans cannot do this. Squids and whales are about the only water animals that can compete with the fish in this respect, and the fish far outnumber them.

This swimming ability has made it possible for fish to dominate most water environments. They live in the oceans, right down to the deepest parts. They live in rivers, lakes, and ponds. They eat both plant and animal foods, large and small.

Fish are important to man as food. Large numbers are taken from the oceans and from inland lakes and streams. Fishing for sport is also very popular. It is one of the main attractions in many vacation areas. Much money is spent in renting cottages and boats and in buying food and fishing tackle. This makes the resort business one of the main industries in several states.

The amphibians. The salamanders, frogs, and toads belong to the ***amphibian*** class of vertebrates. As adults most of them have legs and lungs, so they are able to go out on land and breathe air. Yet their thin, moist skin loses water easily by evaporation. Amphibians are always in danger of drying out. As you read in Chapter 12, they usually live in moist places. Adults may be found on the land, but they return to the water to breed. This means that they are not likely to be far from a pond, lake, or stream. In other words, amphibians are partly adapted to land life but they are not efficient land animals. They cannot compete with fish in the open water. They cannot compete with higher animals on the dry land. They are animals of the shores, ponds, marshes, swamps, and low meadows. In these places, amphibians may be better adapted than any other vertebrates. Frogs, especially, are often very numerous.

Salamanders are lizard-shaped amphibians. But they are not lizards. Lizards belong to the reptile class. Most of the salamanders are only a few inches long, though in the eastern mountains there is one kind that becomes a foot and a half long. Another type, found in Japan, may grow to be five feet long.

You can tell a salamander from a lizard in several ways. The salamander has the smooth, moist skin of an amphibian. A lizard's skin is dry and

Fig. 34-6. A salamander. The first vertebrates on land were probably salamanders with this same lizard-like shape. Salamanders are related to the frogs rather than to the lizards. (Annan Photo Features)

scaly. Salamanders have no claws. Lizards do. Salamanders have a blunt-nose and a pop-eyed look. They are generally slow in their movements. Lizards are usually swift. Salamanders hide in damp places. Turning over old logs in the woods is one way to find them. They are perfectly harmless and can be picked up.

Frogs are a more highly developed type of amphibian. Adult frogs lack the primitive, swimming tail of the salamanders, and their hind legs are specialized for jumping. This gives them a way of escaping their enemies, and you may find them in fairly open places. They often live along a shore and dive into the water when they are frightened. There are more frogs than any other kind of amphibian. Some of them even live in such unusual places as treetops. You will study frog structure in Chapter 47.

Toads are related to frogs and look

Fig. 34-7. Two common types of frogs. The large one is the bullfrog and the small one is the common leopard frog. (Lynwood M. Chace)

very much like them. But their legs are shorter, and their skin looks warty. They can absorb water through this rough skin, so that rain and dew keep them moist. They spend most of their adult life on land, even hibernating on land in holes which they dig with their hind legs. Frogs hibernate in the mud, under water. Toads spend only a short time in the tadpole stage. They are already toad-shaped by the time they are half an inch long. At this time they come hopping out of the water.

You may wonder how these harmless little animals that hop so slowly can escape their enemies on land. The two large warts on each side of the toad's neck are poison glands. If a dog or fox or bear swallows a toad the animal becomes very sick from the poison and coughs up the toad. This teaches the animal to leave toads alone.

Importance of the amphibians. Amphibians are insect eaters. This makes them useful in controlling insect pests. Frogs may eat a great many grasshoppers and leafhoppers in low meadows. Toads are the most useful to man, because they live on higher ground. They come into our crop lands and eat harmful insects.

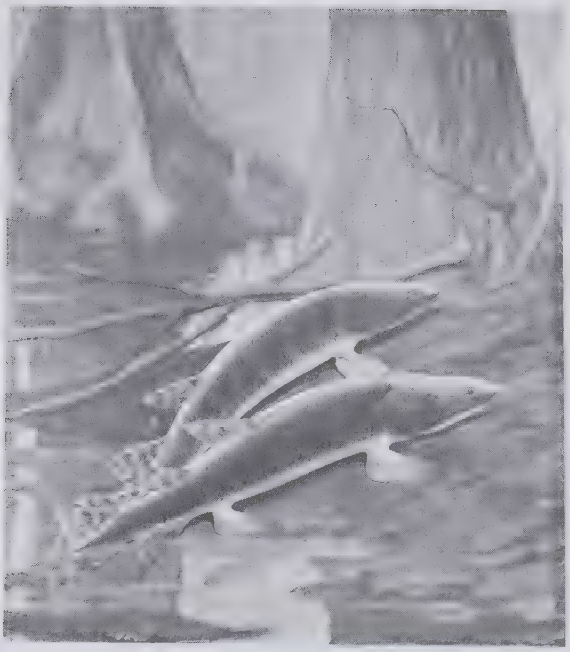
History of the amphibians. The study of fossils shows that the first vertebrates were fishes. One group became adapted to life in swamps. They had gills like other fish, but they also had thin-walled bladders opening into their throats. These were used as lungs, to absorb oxygen from the air. When the swamps dried up or the water became foul, they did not die.

Fig. 34-8. An American toad singing. Why are toads considered to be so useful to man? What keeps them from drying out on land? (L. Edward Rue III)

Another adaptation of these early vertebrates was *lobed fins.* The movable, paired fins had solid fleshy bases next to the body. With fins like these, the lobe-finned lungfish could move across land from one pool to another.

You may wonder why land animals did not eat these clumsy, walking fish. At that time there were no land animals other than insects. The lobe-finned fish did not need to be well adapted to land life. They had no competition on land. On land they found a number of new food supplies. Gradually, through mutation and natural selection, their descendants became better and better adapted to their new home. The lobed fins were modified to become legs. Adults lost their gills. The lobe-finned lungfish had become amphibians (see Fig. 34-9).

Amphibians first appeared on the land about 300 million years ago. They continued to be the main land animals until the end of the Coal Age, about



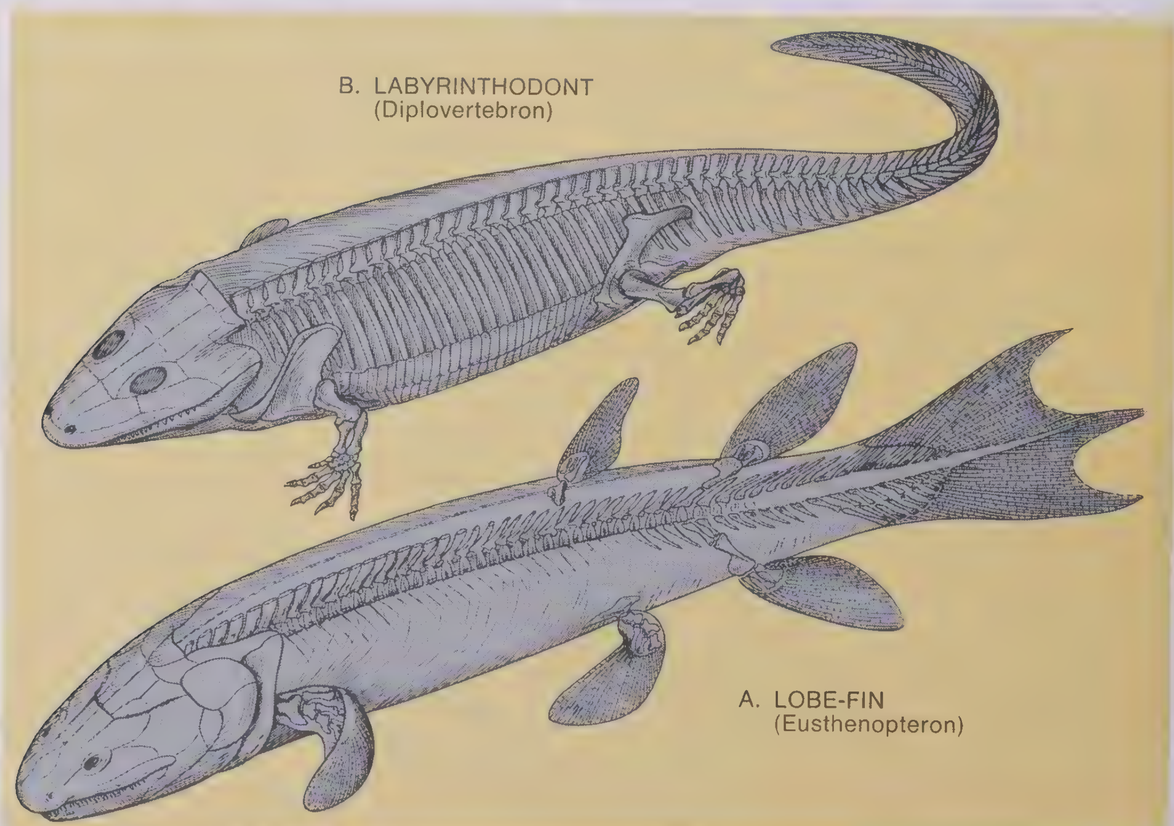


Fig. 34-9. Top left: an artist's idea of how early lobe-finned fish looked when they first came out of the water on to the land. Top right: early amphibians. The bottom drawings show the skeletons of these animals which have been found as fossils. (American Museum of Natural History)

75 million years later. Huge salamanders as big as alligators crawled about the swamps among the giant horsetails and tree ferns.

During this time one group became much better adapted to land conditions than the rest of the amphibians. These modified amphibians gave rise to the first reptiles.

They spread out into many of the drier environments where the amphibians had never been able to live. Even in the swamps the reptiles replaced many of the amphibians. At the end of the Coal Age most of the amphibians were gone. The great age of reptiles was about to begin.

ACTIVITY

1. **Observing the frog.** Chapter 47 is entirely about the frog. Perhaps your teacher will wish to have you make some of the observations that are described at this time instead of later.

2. **Keeping live amphibians.** Frogs and salamanders can be kept in terrariums. Feed them live worms and insects or give them bits of meat as directed in Chapter 47. Newts are salamanders that can live in aquariums like fish. Japanese newts will pick up pieces of meat from the bottom. With other newts you must move the meat or they will not take it.

3. **Keeping live fish.** Probably your teacher has already set up aquariums in the room. If not, this is a good time to do it. Each aquarium should have sand or gravel in the bottom. Water plants like *Vallisneria*, *Myriophyllum*, or *Elodea* should be planted in the sand. Fill the aquarium with water and let it stand a day or two before adding fish.

Do not put in too many fish. The number and kind of fish you can use will depend on your equipment.

CHECK YOUR FACTS

1. **What are the vertebrates? How can you recognize a vertebrate?**
2. **What are the three phyla of fish?**
3. **How do fish get their oxygen?**
4. **What is the swim bladder used for?**
5. **Of what importance are fish?**
6. **What are amphibians?**
7. **How can you tell a salamander from a lizard?**
8. **Why do we say that the amphibians are only partly adapted to living on land?**
9. **In what way are frogs and toads useful to man?**
10. **When did amphibians first appear on the earth? Where did they come from?**

CHAPTER 35

Reptiles and Birds

Members of the reptile class were the first really well-adapted dry land vertebrates. Different species became adapted to most of the land environments, and some were even sea animals. There were big, small, and medium-sized reptiles. You will remember that the greater part of this Age of Reptiles was also the Age of the Nonflowering Seed Plants. Cycads, redwoods, and ginkgos were common during this period.

The biggest reptiles were giant dinosaurs. Some of them were 80 feet long and weighed about 50 tons. They were the largest land animals that have ever lived. The big reptiles lived on for a time after flowering plants had appeared, but then the Age of Reptiles ended. Most species of rep-

Fig. 35-1. A view of what the world may have looked like in the Age of Reptiles. All plants and animals in this scene are known today from fossil remains which have been unearthed by scientists. (Courtesy of The American Museum of Natural History)

tiles died out. We do not know all of the reasons. The climate changed, becoming cooler and drier. Perhaps early mammals destroyed some reptiles by eating their eggs or, possibly some reptiles were killed by diseases. Whatever the cause, the dinosaurs vanished about 75 million years ago. They had dominated the land for over 100 million years, but finally they were all gone.

The reptiles which survive to this day include the lizards, snakes, crocodiles, and turtles. If you wonder what it would be like to find some ancient form of reptile still living, look at a turtle. Turtles were on the earth as early as the dinosaurs. They have been here ever since. Our modern species are "living fossils."

Characteristics of the reptiles. Reptiles have a number of traits which make them better adapted to land than amphibians. The reptile skin is dry and covered with scales, so that more moisture is held in the body. The lungs and circulatory systems of reptiles are more efficient than they are in amphibians. Reptiles reproduce on land, as you learned in Chapter 12.

But reptiles have some disadvantages. For one thing, they are cold-blooded. They seek the sunshine when they need heat. They crawl into the shade when they are too hot. They must be inactive in really cold weather. They also have low intelligence when compared with mammals. Their third disadvantage is in their reproduction. Reptiles do not care for their young. You can begin to see the advantages birds and mammals have in their competition with the reptiles.

The ***lizards*** are mostly fast-moving insect eaters. One of them is shown in Figure 35-2. They live mainly in warm countries. Some can have their tails broken off without harm. While an enemy springs on the wriggling tail, the lizard escapes. Later, it grows a new tail. Most lizards are small, but a few tropical species are fairly large. The biggest is the dragon lizard of Indonesia, which may reach 15 feet

Fig. 35-2. The green lizard. It has a dry, scaly skin, ear openings, and claws on its toes. These are some of the traits which will help you to tell it from a salamander. (Eric Hosking, F.R.P.S.)

Fig. 35-3. The dragon lizard of Indonesia. It is nearly as big as an alligator and it hunts its food on land. (W. Suschitzky)

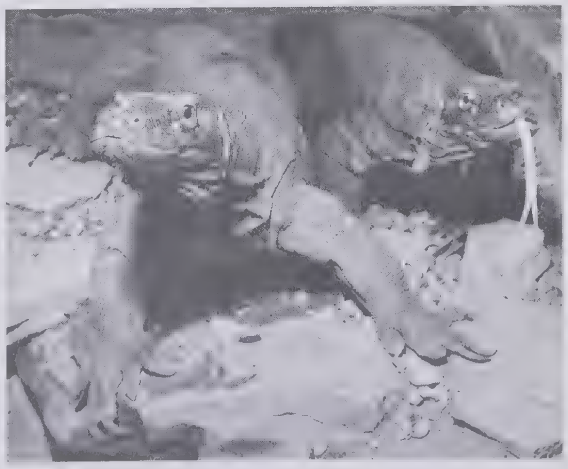


Fig. 35-4. A freshwater turtle. (Jack Dermid)

Fig. 35-5. A large Green Sea Turtle. Note how its feet have evolved into flippers. (Walter Dawn)

in length (Fig. 35-3). It hunts animals as big as deer.

Turtles have bodies specialized for defense. The shell is made of surface plates plus the ribs, backbone, and breastbone flattened out and grown together. Most turtles escape from land animals by sliding into the water. Few water animals are able to hurt them because of their strong shells. The box turtle, however, spends most of its time on land. The names *turtle, terrapin, and tortoise* all refer to members of the group we call turtles.

The largest freshwater turtles in North America are the snapping turtles (Fig. 35-4). The northern species may weigh 40 pounds and the southern 150. These snapping turtles are dangerous to handle. They have no teeth, but the sharp beak can cut off fingers.

The biggest turtles of all are the sea turtles. The giant sea turtle may

Fig. 35-6. Left: the American crocodile and right: the African crocodile. Both are members of the same family and are much alike. (Leonard Lee Rue III; South African Information Service)

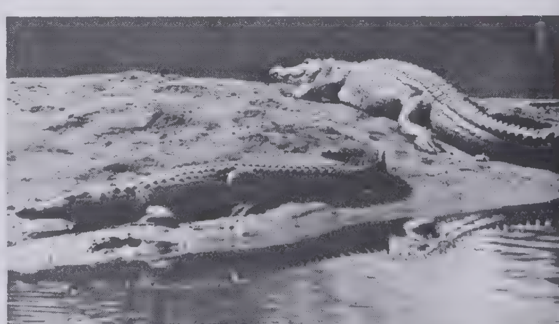


Fig. 35-7. Two common snakes which are harmless. Left: the king snake and right: the blue racer (Walter Dawn; Courtesy The American Museum of Natural History)

weigh as much as 1,400 pounds. These reptiles have their toes grown together to form flippers. They spend their entire time at sea, coming ashore only to lay eggs.

The ***crocodiles*** and ***alligators*** are lizard-shaped, but much bigger and heavier than the lizards. Most of them live in swamps and along river banks. They eat fish and any land animals which come within their reach. Some species are not likely to attack man. Others are man-eaters. The African crocodile eats many more human beings than do the lions and leopards. The American alligator seldom bothers man. The American crocodile, however, is sometimes vicious.

Snakes, with their long legless bodies, seem to survive because of their ability to hide easily. They all eat small animals, which must be swallowed whole. The jaws of a snake are very flexible and can stretch far out of joint. This is why they are able to swallow food thicker than themselves.

When a snake attacks another animal, it has no feet or claws to use. Its long body may get injured as the victim fights back. Different kinds of snakes have various ways of meeting this danger. Some eat only harmless animals. The garter snake, for instance, feeds on worms, insects, frogs, and toads. It simply grabs its victim and slowly swallows it.

Other snakes use a wrestling method. They wrap their bodies around the animal's chest and squeeze. This does not crush the victim, but it prevents it from breathing. The victim is soon dead and the snake can go ahead with the slow business of swallowing it. The bull snake and fox snake take mice in this way. The biggest snakes of all, the pythons and boas, also use the squeezing method. The largest of these are about 30 feet long.

The third method by which snakes kill their victims is to use poison. Poison quiets the victim quickly. The poison comes from glands in the neck. There are three groups of poisonous snakes—the *vipers*, the *cobras*, and the *rear-fanged serpents*. The rear-fanged snakes have two poison fangs in the back of the mouth. Because of

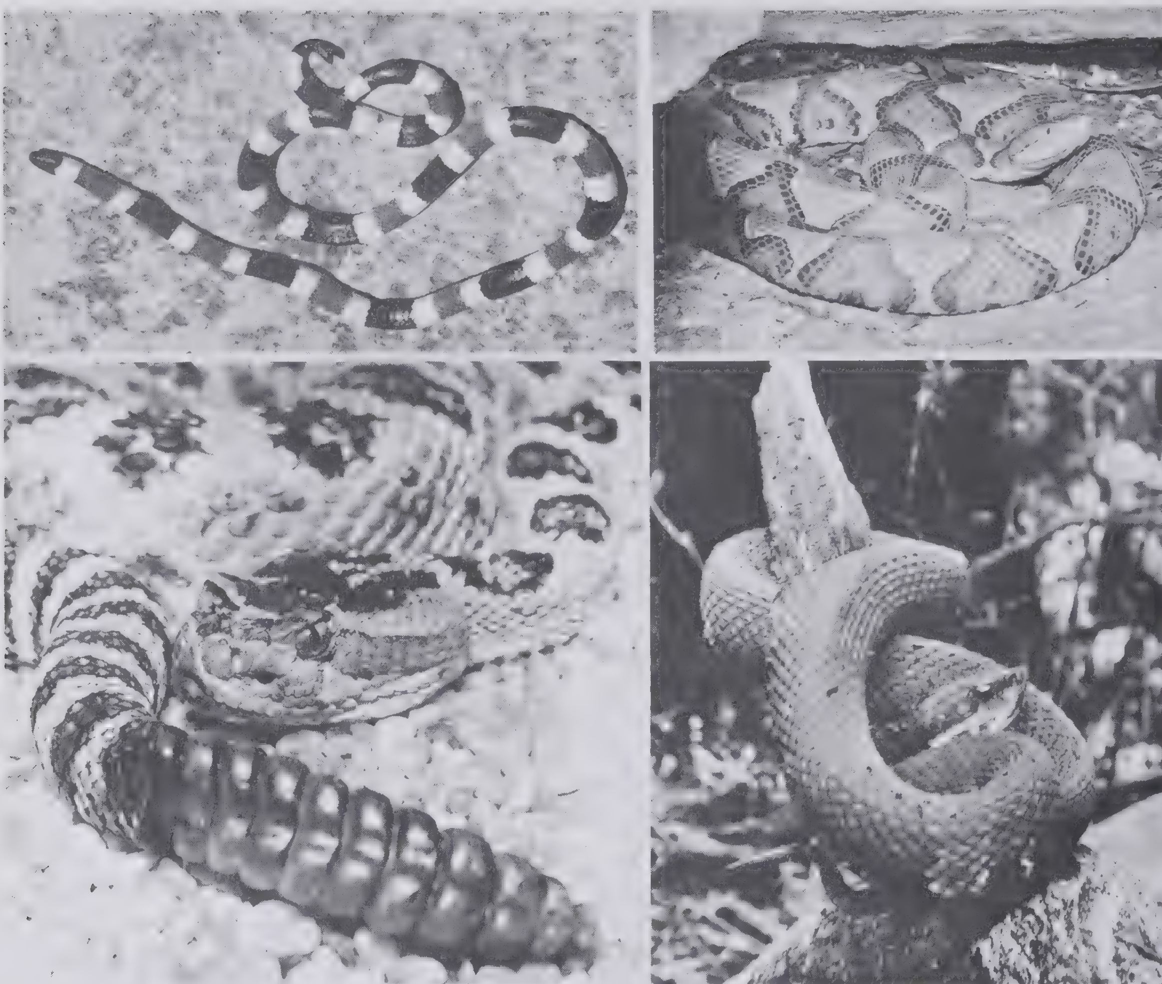


Fig. 35-8. Four common snakes that are poisonous. Top left: the coral snake whose bands are black, yellow, and red. Top right: the copperhead. Lower left: one of the many species of rattlesnakes. The rattles are made of old, dried layers of skin. Lower right: the water moccasin (also called the cottonmouth). This is a southern snake that lives in swamps. (Courtesy of The American Museum of Natural History; all others Walter Dawn)

this location of the fangs they cannot easily use them on large animals, so they are seldom dangerous to man. There are a few species in the southern United States.

The cobra-type fangs are short and hollow and are in the front of the mouth. These snakes grab their victims and chew to force in the poison. Two species of ***coral snakes*** are the only members of this group in North America, except for a few tropical sea snakes which may wander as far north as the south California coast.

The vipers of America all belong to a group known as the *pit vipers*. They have a pit-like sense organ on each side of the head. Many Old World vi-

pers do not have this. The pit is very sensitive to heat. With it these snakes can detect a mouse or other warm blooded animal hidden in the grass. Why do you suppose no mammal has developed such a sense organ?

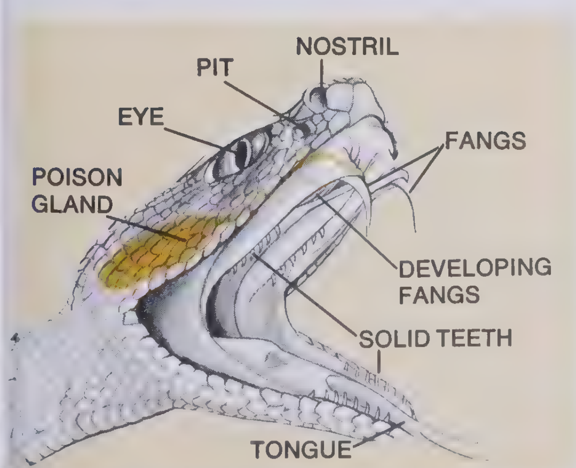
The pit vipers include the most common poisonous snakes in America, the **rattlesnakes, water moccasin,** and the **copperhead.** Their fangs are so long that they must fold back when the snake closes its mouth. The fangs are driven into the mouse or rat or other victim with a very swift stabbing movement of the head and neck. Then the snake lies back and waits while the victim dies.

Poisonous snakes are not common in most parts of the country. There are many areas that have none of them. Find out which dangerous ones live in your area. Look out for them, but do not fear the others. Most snakes are perfectly harmless.

More people are bitten by the copperhead than any other North American snake. It matches the dead leaves on the forest floor perfectly, and people step on it by accident. Very few people die from such bites, for the copperhead is not a large snake and does not have a great deal of poison. Any fairly good first aid or medical treatment will save the person's life. He *will* suffer, however. The snake most likely to kill a man is the Texas diamondback rattlesnake. It is large, and it has a great deal of poison. Most snakes fear people and try to keep out of their way, but the Texas diamondback is different. It will actually edge closer, to get in a position to strike.

Many snakes have a nervous habit of vibrating their tails when they are excited. The rattle on the tail of a rattlesnake produces a buzzing sound at such times. This helps you to avoid the snake, but do not depend upon this warning signal. Sometimes a snake will strike without rattling first.

Fig. 35-9. Teeth of the rattlesnake. The long fangs are like hypodermic needles for injecting poison. They fold back when the mouth closes. The other teeth are the common needle-pointed type found in all snakes.



Importance of the reptiles. Reptiles are not numerous in most places, and their importance today is not great. What effect they do have is mostly good from our point of view. The smaller snakes and lizards eat many insects. Some other snakes eat large numbers of mice and rats which would otherwise destroy our crops.

The skins of alligators, crocodiles, and the larger snakes and lizards are used to make leather. A number of turtles are eaten by man. People in some parts of the world also eat snakes and lizards. In Florida the alligators dig ponds in the marshy areas. These become important water holes for all kinds of wildlife during the dry seasons. This is one reason why

the alligator is protected from hunting in that state. Of course we do not want poisonous snakes near our homes, but even these snakes are useful, in a way, because they destroy pests.

Adaptation to flight. Suppose that you were told to change a reptile into a flying animal. You were given the power to change anything that was already there, but you could not add anything new. How would you go about it?

In the first place you would wish to give it some wings. This could be done by modifying the front legs. It would be best to choose a reptile that already walked on its hind legs, as some of the dinosaurs did. To give large wing surface, scales could be greatly enlarged to form long stiff feathers.

Flying is very difficult work. The wing muscles would have to be enlarged. Heart and lungs would have to be more efficient. Protoplasm delivers more energy at higher temperatures, so you would speed up the oxidation of food, making this reptile a warm-blooded animal. The body heat would need to be held in, and feathers would help to do this.

Flying animals should be light in weight. So, the long reptile tail should be shortened down to a mere stub. Lightweight feathers growing out of this stub could do the steering. The heavy reptile teeth could be replaced by a light, horny beak. The bones could be reduced in weight, many of them becoming hollow and filled with air.

You will notice that no change has been made which was not needed for flight. The final result is no longer a reptile. It is a bird. This is how many biologists believe the birds were developed. Small reptiles of the dinosaur type became adapted to flight, through a long process of mutation and natural selection.

Fig. 35-10. Birds in flight. The animals are beautifully adapted for flight. How did they get this way? (Walter Dawn)

Birds—a very successful class of vertebrates. The two main foods of birds are insects and seeds. Both of these foods give the large amounts of energy needed for flight. The ability of birds to fly makes them better insect catchers than either the reptiles or the mammals. Seeds often grow on the ends of branches and stalks, so that flight also helps in gathering them.

Certain birds eat other things.

Hawks hunt small mammals and reptiles. Loons, pelicans, and some of the ducks dive for fish. Vultures eat dead meat. You have probably seen robins catch worms. All of these are exceptions, however. Most birds feed on seeds or insects.

No flying bird eats grass or leaves. These are low-energy foods. Too much of them would be needed to power a flying animal. Also, flight would not help a grass-eating animal. The grass will not run away, and wings are actually in the way on the ground. Mammals are much better adapted to eating plants. So birds and mammals share the land environment. Each type lives where it can find food and escape destruction by its enemies.

Bird study. Studying birds is a favorite hobby of many people. Birds are the only wild animals that are easily seen in the daytime in settled parts of the country. You can even watch them in a backyard or in a city park. If you would like to learn the different kinds of birds, get a book with colored pictures in it. Compare the pictures with the birds you see.

The beaks and feet of a bird can tell you a great deal. Look at Figure 35-11. Short heavy beaks are used for cracking seeds. Slender, lightweight beaks are good for catching insects. Flat beaks can shovel around in mud to catch worms and snails. Long, spearlike beaks can catch fish and frogs. Hooked beaks can tear small mammals into pieces that a bird can swallow. Can you name birds with each of these types of beaks?

The feet of birds may also tell a story. They may be adapted for perching on twigs, for walking, for swimming, for wading, for scratching the ground for food, for killing small mammals, or for clinging to tree trunks (see Fig. 35-12). Learning to observe such things as beaks and feet will help you to know the different birds.

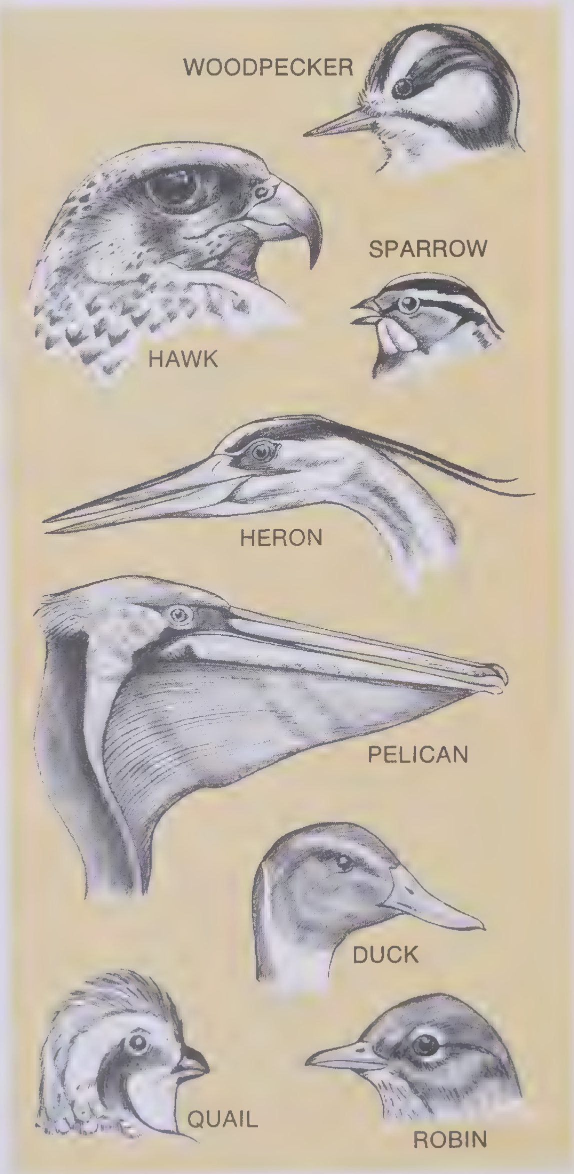


Fig. 35-11. Bird beaks. What sort of food getting is each beak best adapted for?

Migration of birds. One of the most interesting things about many birds is their migration flight. Most birds which live in the north fly south for the winter. Probably they do not migrate just to escape the cold. With their warm bodies and feather covering, birds can withstand cold weather very well. Very likely most birds fly south because their food supply is gone. Insects are not active in the winter. Some seed-eating birds, like the cardinals, can still find food. They stay in the north all winter. So do woodpeckers, owls, chickadees, field sparrows, jays, and several others. Each of these birds eats foods which are available in winter weather.

Why do birds return north again? When birds nest in the spring they need large amounts of food to feed their growing young. By spreading out over more territory, more birds can find this needed food. This is one important advantage of migration. It enables more birds to find enough food to raise their young.

Of course birds do not know why they migrate. They do so by instinct. When the days become a certain length each spring, the birds respond by flying north. At this time the bird's sex organs are beginning to become active. In the fall, as the days become shorter, birds respond by migrating back to the south.

The distances traveled by birds during migration are surprising. The house wren goes from Canada and the northern states to Florida, the wood thrush to southern Mexico, and the bobolink to Argentina. The arctic tern nests in the arctic, then migrates to southern Africa and South America, as far as 11,000 miles away. The golden plover, a land bird, may fly nonstop from Labrador to Brazil—2400 miles over water.

Flights like this not only call for great flying ability, they also call for good navigation. How birds find their way on long flights has been a mystery to biologists. There is one theory that birds navigate by the position of the sun during the day and stars at

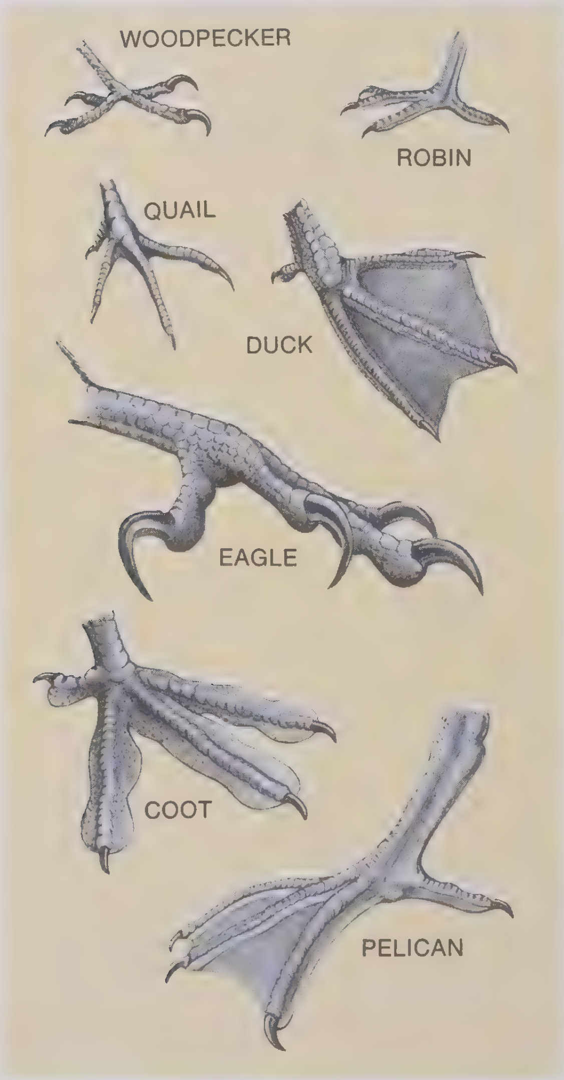


Fig. 35-12. Several kinds of birds' feet. What adaptations does each type of foot show?

night. The height of the stars tells how far north or south they are. By using their keen sense of time and by watching the movement of stars across the sky, they may know how far east or west they are. Ship captains navigate in the same way, but they need instruments and mathematical training to do so.

Importance of birds. Since there are so many birds, they affect the communities in which they live in many ways. As eaters of insects and of weed seeds, they are very useful to man. Hawks and owls are important in keeping meadow mice and other pests in check. Some birds, such as chickens and ducks, are raised as domestic animals. They furnish us with both meat and eggs.

ACTIVITY

Observing reptiles and birds. 1. **Turtles.** To keep living turtles in the classroom prepare a cage that gives them a choice of being in or out of water. Feed them pieces of meat dropped in the water. The box turtle will eat on land. It needs no water to swim in, but supply it with a dish of drinking water. You can feed it vegetables.

2. **Snakes.** Small snakes are more difficult to keep alive. It is best to bring them into class for a few days and then turn them loose again. Some will bite, and some will not. They are less likely to bite if you handle them gently. Do not jerk. Do not squeeze them behind the head. A good pair of gloves will protect you from their tiny teeth. Of course you should not try to handle the poisonous ones, and do not bring poisonous snakes to school!

Some snakes can be kept alive by feeding them live mice. One feeding a week is enough. Garter snakes will often take live worms or minnows.

3. **Birds.** Have a supply of bird guides and bird charts in the classroom. Each student can watch for birds in parks or in his neighborhood. Identify them from the books and charts. Keep a list of the kinds of birds you have seen.

CHECK YOUR FACTS

1. **In what ways are reptiles better adapted to land than are the amphibians?**
2. **What disadvantages do the reptiles have as land animals?**
3. **What are the four main groups of reptiles living today?**
4. **How can snakes swallow animals thicker than themselves?**
5. **What are three ways in which snakes capture their food?**
6. **What are the three main types of poisonous snakes?**
7. **Are most snakes useful or harmful? Why?**
8. **In what ways are birds adapted to flight?**

9. The legs and hips of birds are the same as the hips and hind legs of some ancient dinosaurs. Can you think of an explanation for this?
10. What are the main foods eaten by birds?
11. How do beaks and feet of birds adapt them to different ways of living?
12. Why do birds need to migrate (both ways)?
13. Of what importance are birds?

CHAPTER 36

The Mammals

Mammals differ from reptiles in several ways. Like birds, mammals are warm-blooded. This enables them to be active even when the weather is cold. In fact, it may be that the first mammals developed from an ancient race of reptiles. Some of these old reptiles kept right on being reptiles. But another group became small mammals that were adapted to a cool climate.

Just as all birds have feathers, all mammals have hair. There are mammals such as whales that do not have very much hair, but they always have some. The fur of the mammal helps to hold in body heat. Another characteristic of the mammals is their learning ability. Their brains are more highly developed than those of the reptiles, making them more intelligent. You already know about mammal reproduction. They care for their young. Female mammals produce milk to feed their young. No other animals do this.

All of these things give mammals an advantage over reptiles. The first mammals appeared in the middle of the Age of Reptiles, but their big chance did not come until most of the reptiles disappeared. For the last 75 million years mammals have been the most successful of all the vertebrates on the land.

There are mammalian species adapted to almost every environment. There are not as many insect-eating animals among them as might be expected. The birds compete more successfully for such food, but the seed-eating mammals are at least as successful as the birds.

Orders of mammals. There are many orders of mammals. The following list describes the more important ones.

1. *Egg-laying mammals.* You have studied their reproduction in Chapter 9. Modern species are the *duckbill* and the *spiny anteaters* (Fig. 36-1). They are interesting to biologists because they are the most primitive living mammals. In their reproduction and in their structure they are more like reptiles than any other living group of mammals.

2. *Pouched mammals.* These are the main mammals of Australia and nearby islands. A variety of these pouched mammals have developed there and they are adapted to many different ways of living. Female mammals of this order have pouches in which they

Fig. 36-1. A spiny anteater. This primitive mammal species survives from the early days of mammalian evolution. It still lays eggs, like a reptile. (Australian News and Information Bureau)

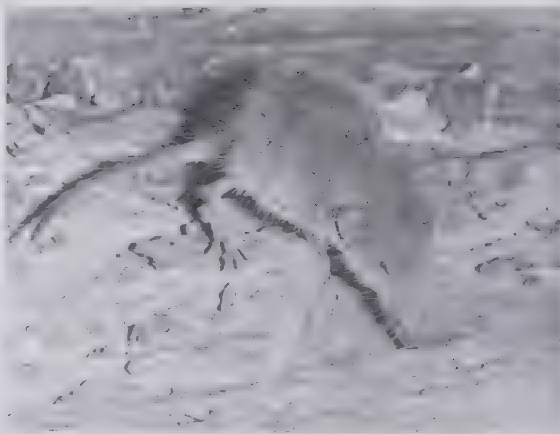


Fig. 36-3. A common type of shrew. There are a great many of these little insect eaters in North America but they stay out of sight so you seldom see them. (R. H. Noailles)

carry their young (Chapter 9). Kangaroos feed on grass; koalas climb trees and eat the leaves; wombats look and act like woodchucks; the Tasmanian wolf hunts other animals. There are squirrel-like, mouse-like, and mole-like forms of pouched mammals in Australia. In general this group is not able to compete well with the placental mammals. Their low intelligence is probably one reason. Pouched mammals have survived in Australia because the ocean has separated them from the placental mammals of Asia since very early times.

Fig. 36-2. An opossum. This pouched mammal has changed little since the Age of Reptiles. (Gordon S. Smith from National Audubon Society)

One group of pouched mammals does survive in competition with other mammals. This is the opossum group (Fig. 36-2). The common opossum of the United States and southern Canada is a "living fossil." Opossums lived in the Age of Reptiles. Opossums are slightly bigger today, but otherwise they have not changed much in the last 100 million years.

3. *The shrews and moles.* These mammals are insect eaters. You probably know that moles live underground. Shrews are not so well known, yet they are the most common mammals in many areas. An ordinary shrew is the size of a mouse, but its nose is much more pointed, and its fur is thicker (Fig. 36-3). Many shrews are almost blind. They hunt insects on the ground and under dead leaves. They have many sharp little teeth. The pigmy shrew is only half as long

Fig. 36-4. A bat in flight. Note how its body is surrounded by one big wing. Also note the large ears. In what special way is hearing used by bats? (Eric Hosking from National Audubon Society)

as a mouse. It is the smallest of all the mammals.

4. *The bats*. *Bats* are much like the members of the mole and shrew order, except that they have wings. The front toe bones are long, with skin stretched between them. The wing skin continues from the front limbs to the hind legs and then on around to the tail (Fig. 36-4). Since front and hind legs are both part of the wing, bats cannot walk very well. They either fly or they hang head down by the claws of their hind legs. Bats fly at night, taking insects out of the air. By day they hang in such dark places as caves, hollow trees, or attics. North American bats are considered very useful to man because they eat many insect pests.

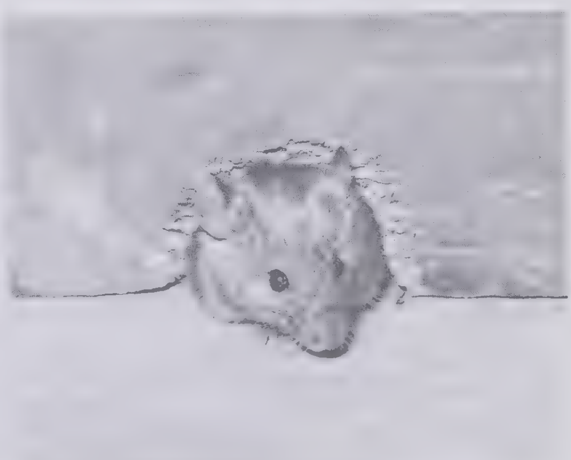
A few bat species in the tropics eat other food. Some very large forms, with wingspreads of three feet or more, eat fruit. One large species in South America hunts like an owl. A smaller South American type, the vampire, laps the blood of large animals after slicing the skin with razor-sharp teeth. It may even attack sleeping people.

Bats can fly in complete darkness. They find their way by listening to the echoes of their own high-pitched voices bounding back from the objects around them. This is the same principle as sonar, which is used to detect submarines and to tell how deep the ocean is. In fact, the inventors of both sonar and radar got the idea from a study of bats.

5. *Rodents and rabbits*. *Mice*, *rats*, *squirrels*, *woodchucks*, *porcupines*, *muskrats*, and *beavers* are a few kinds of rodents. Rabbits are very much like them, but they are placed in a separate order. Rodents eat rough plant foods, using their heavy gnawing teeth in front and strong grinding teeth behind. Mice are mainly seed-eating animals. Squirrels eat nuts and twigs. Woodchucks eat grass. Most rodents also eat some insects.

The rodents are very successful animals. Their kind of food can be found

Fig. 36-5. The common house mouse. This little rodent has chewed its way through the timbers by means of extremely sharp teeth. (Leonard Lee Rue III)



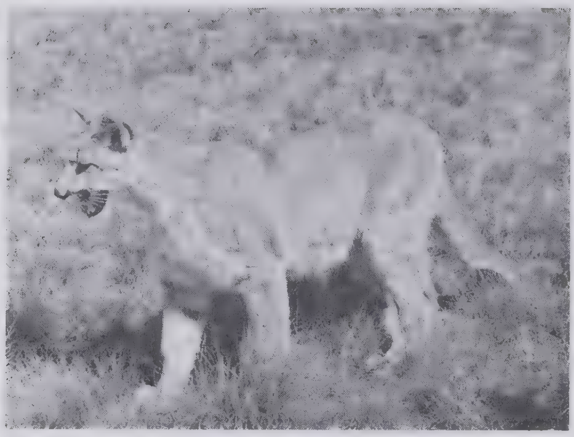


Fig. 36-6. The mountain lion is also called the cougar, painter, panther, puma, and catamount. A member of the flesh-eating order, it has special adaptations for hunting. What are they? (Colorado Game, Fish, and Parks Dept. Photo by Don Domenick)

almost everywhere. They can hide easily because of their small size. They can reproduce more rapidly than larger mammals. Some, such as the squirrels, are eaten by man. Some furnish valuable fur. But mice and rats give man some very troublesome competition. They eat our crops in the fields and in storage. They do damage to our buildings, and sometimes they carry diseases.

7. *The flesh eaters.* This order includes the *dog* family, *cat* family, *weasel* family, *bears*, *raccoons* and *seals*. These animals have teeth for catching and killing other animals, which they use for food. The flesh-eating mammals are more intelligent than most other animals. They serve a useful function in the wild communities where they live by keeping the plant eaters in balance with their food supply.

We have killed off the larger flesh-eating mammals in the settled areas of our country, but the smaller ones, like foxes, raccoons, weasels, and mink continue to live in large numbers, even close to cities. The Alaskan brown bear and the polar bear are the largest members of the flesh-eating order.

8. *Whales. Porpoises*, *dolphins*, and *whales* are mammals shaped like fish. Although they breathe air, they live

Fig. 36-7. These wooly rhinoceroses became extinct in Europe thousands of years ago. Where do members of the rhinoceros family live today? (Courtesy of The American Museum of Natural History)

Fig. 36-8. The tapir. This tropical relative of the horse and the rhinoceros is a member of the odd-toed order of hoofed mammals. (W. Suschitzky)

their entire lives at sea. They have evolved from land mammals that became adapted to life in the water. The blue whale is the largest animal that has ever lived. It may be over 100 feet long and weigh over 140 tons.

9. *The elephants.* There are two species of elephants alive today, the *Indian elephant* and the *African elephant.* There have been several others in the past. Six species lived in America. Mammoths and mastodons were elephants which died out in America within the last 9000 years. Early Indians hunted these species, and this may be what caused their extinction.

10. *Hoofed mammals.* There are two orders of these mammals. The members of both have hoofed feet and they are all plant eaters. They depend upon running away to escape from their enemies.

The animals in one of these orders have an odd number of toes. These include the horse, rhinoceros, zebra, and tapir. Animals of the other order have an even number of toes—the so called "cloven hoofed" animals. Deer, sheep, goat, pigs and cattle are a few of the many members of this group.

The flesh of hoofed mammals has been important food for man for many thousands of years. First he hunted them. Later he tamed them. Cattle provide meat, milk, and leather. From

Fig. 36-9. A large herd of caribou running across the ice and snow of the frozen north. Herds of these animals travel many miles in the constant search for food. (Province of Quebec)

pigs we also get meat and leather. The horse has played an important part in human history. It has been a swift mount for riders. It has also served to pull a great many wagons and plows.

12. *The primates.* This order includes *lemurs*, *monkeys*, *apes* and *man*. The primates are mainly tree climbers, with grasping hands and high intelligence. Man is different from the others in being a species that lives on the ground and walks upright on his legs. Thus his hands are free for using tools.

ACTIVITY

Local mammals. 1. Each member of the class should find all the information he can about some mammal which lives in his part of the country. It can be a wild animal or a farm animal. Then each student can report this information to the class.

2. **Mammal skulls.** There is often a collection of mammal skulls in a biology room. If your school has one, make a study of these skulls. How much can you tell about the animal just from this one part? Scientists who study fossils are often faced with this sort of problem.

In skulls, it is often the teeth that tell the story. In rodents see how the front teeth are like chisels, for gnawing hard food materials. See how the back teeth have ridges of hard enamel for grinding this hard food. Next look at the skull of a cat, dog, or other flesh eater. Notice the fangs for killing and the back teeth for cutting up meat. These teeth would not be good for chewing grass. Next look at the teeth of some variety eater like man, a bear, or a pig. See how the chewing teeth are about halfway between those of the rodent and flesh eater. They can chew fairly well, but will not handle the really heavy job of grinding grass or bark. A bear still has killing fangs, for it is a member of the flesh eating order, but a bear's back teeth show that it eats a great many plant foods. These need more chewing. Now look at all the other skulls, and try to explain them in this same way? What did each animal eat?

3. **A trip to the zoo.** If there is a zoo in your area go and study the mammals. List all of the types that you see. Arrange your list so that all members of each mammal order are grouped together (the zoo may include a few animals from orders we did not study). Opposite each name give your observations about the animal. What adaptations does it show for food getting? What food does it eat? What means of defense does it have? What is its position in the community when it lives in the wild?

CHECK YOUR FACTS

1. What are the main characteristics of the mammals?
2. Which of these characteristics give mammals an advantage in competing with the reptiles?
3. List the ten orders of mammals described in this chapter and name some animals that belong to each group.
4. Why are rodents a successful group of mammals?
5. What mammals have been raised and tamed by man? Why are they so useful to man?

CHAPTER 37

Man

We have just finished a quick review of the kinds of living things. Now we shall take a closer look at the most interesting species of all—man. We shall try to see man and to study and to understand him as a biological species.

Compared to other organisms, man is not the strongest, nor the fastest, nor even the boldest. What, then, makes man superior to all other living things? Why did he not vanish from the earth long years ago as some other biological species did who were not fast, nor strong, nor bold? The reason probably is because man has the great gift of coordination of hands, eyes, and brain. He is the only living creature that can perform manual labor or paint a beautiful picture with his hands. He alone of other living things has a thumb which can touch each finger of each hand. He has very good vision and this is one reason he can use his hands to do so many things. Finally, his wonderful brain enables him to store up events in his memory, to dream up new ideas, and to make plans for the future. Good hands and eyes have helped man to survive. But without the good brain they would not have been enough. Man needs the brain to direct the hand and the eye. With this fine control he has become the most superior of all living things.

It is obvious that man belongs to the primate order of animals. One can tell this just from his physical structure. He has the same body structure the other primates have. But he has a brain far superior to that of any other member of the primate order. There has never been another species like him on earth.

What is man? When scientists begin to study fossils it is hard to say which were man-like primates and which were early humans. Changes came on very slowly and scientists find it difficult to draw a line between the two groups. In this book we shall call a group "*human*" if it had a bigger brain than any other one of the primates, or used a variety of tools, or seemed to have had some form of language. More primitive types will be called "*near-humans*."

Where did the first men live? Scientists would like to know where the first near-human and human types lived. But so far, the fossil record has not given them the answer. The known evidence today suggests that about 2 million years ago some higher primates existed in tropical Africa.

We can, however, be fairly sure of some things. The ancestors of these higher primates lived in the rugged outdoors. They walked upright on

Fig. 37-1. Some modern primates. Top left: a baboon; top right: a lemur; bottom left: a monkey; bottom right: an ape. (Satour; C. M. Hladik/Jacana; C. M. Hladik/Jacana; W. Suschitzky)

the ground. They left the forests to live on the savannah. A ***savannah*** is a grassland with trees scattered here and there. On the savannah there are often ponds, lakes, and streams. There also are many small game animals, so there is food for the hunter.

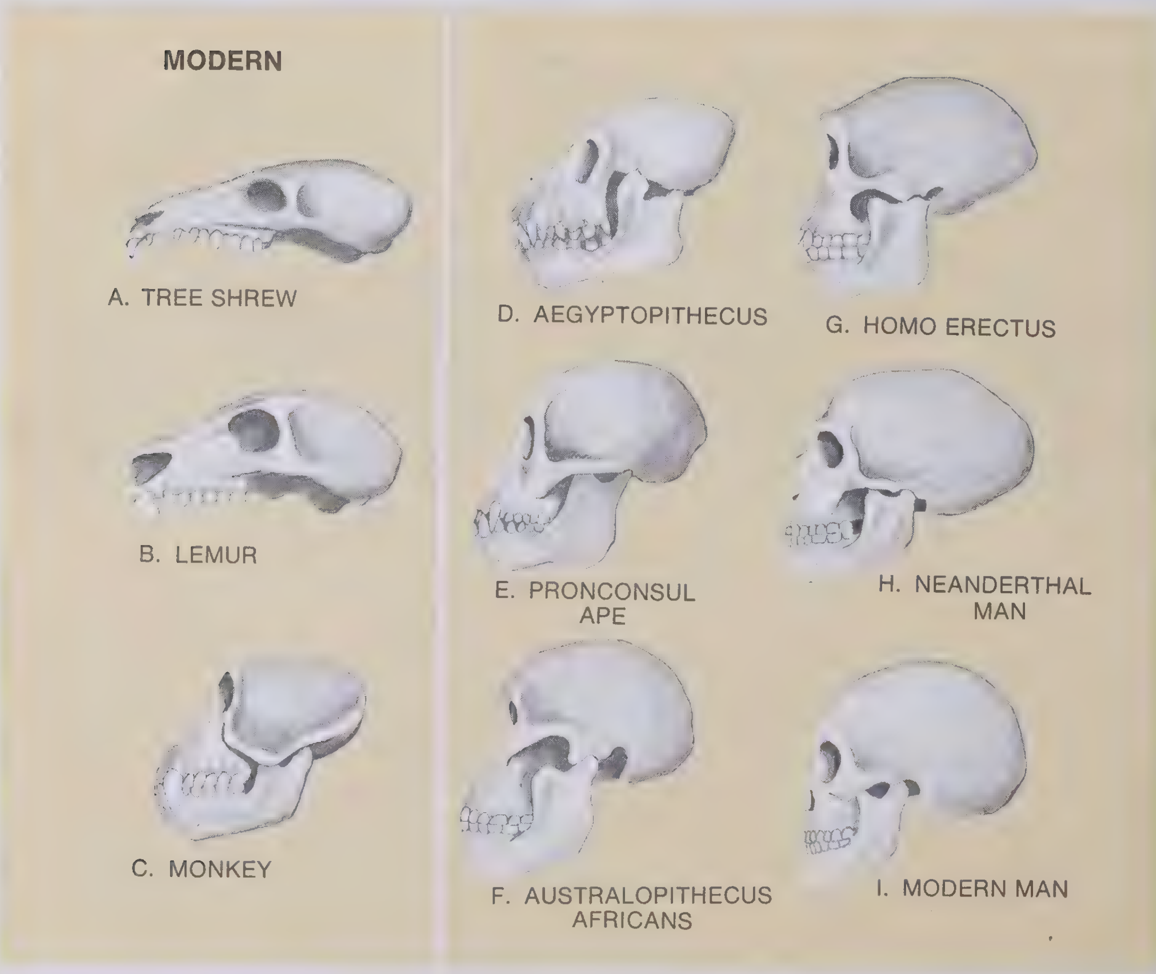
These ancestors of man did not hold a meeting and decide to change environments. No one said, "Let's move to the savannah." No doubt what really happened was that they lived in a forest surrounded by grasslands. Over a period of probably hundreds of years the forests were getting smaller and grasslands were getting larger. The climate was becoming dryer. It was too late to retreat to forests that grew elsewhere. The wide, grassy plains stretched out in all directions.

So here was a group separated from others of its kind. It had a gene pool of its own. When mutations took place, new genes were added to this gene pool. When a gene pool like this is separated from the main gene pool of the species, a new type may develop. Natural selection may adapt the new type to a changed environment. In time, it could become a new species.

Some of the primates who left the forests had traits adapted to life on the grasslands. They survived to hand these traits on to their offspring. But others who were less well adapted died young. Some individuals may have starved to death. Others may possibly have been eaten by wild animals. It must have been dangerous for a long time, because few lived and many died. This was the price of the development of the human race.

Near-human fossils. The best of the old near-human fossils come from Africa. This African type *(Australopithecus)*

Fig. 37-2. Nine levels of development in the primate order of mammals. A. a modern tree shrew; B. a modern lemur; C. a modern monkey; D. earliest known ape; E. early ancestor of the modern apes; F. near-human; G. early man, H. Neanderthal man; I. modern man.



lived nearly two million years ago. Probably it existed long before that, but so far, we have not found the fossils. These near-humans were about four feet tall.

Their bodies were already much like ours. Their legs were long and straight for walking upright on the ground. Their arms were slender and their hands were used for the making of tools. Perhaps they dug roots with sharp sticks. Perhaps they used longer, pointed sticks for defense. We have found some of their clumsy stone implements. These are merely stones that have been broken off on one side to produce a sharp, irregular edge. Such a sharp-edged stone (called a *pebble tool)* can be used for scraping or sawing tough materials. It can even be used for cutting up an animal. They did eat animals, together with whatever plant foods they could gather.

Some other primates will eat meat once in a while, but they are usually plant-eaters. The near-humans had become small game hunters. We find the skeletons of animals like mice and turtles in their old camp sites. These must have been eaten raw, using a pebble tool to open the turtle shells. These ancients did not cook food.

This hunting and the using of tools sounds quite human but these near-humans did not have a very large brain. Their intelligence may not have been much greater than that of other large primates but it was certainly different in the way it worked. The apes seldom use any sort of tool. These near-humans must have depended on tools to survive.

This use of tools was made possible by the upright body. Walking entirely on the hind legs frees the arms for holding things. The grasping hand was already there, an inheritance from the past. So were the good eyes. The near-humans needed their good eyesight to see danger across the plains and to see the small animals that they used for food.

For protection, no doubt the near-humans traveled in groups. This trait was also inherited from primate ancestors. Down on the ground the danger from flesh-eaters was very great, so group loyalty and cooperation must have been important. The near-humans had teeth much like ours but they were not very good weapons. What did they fight with? Perhaps they did not fight. We do not know. The flesh-eaters usually leave man alone.

Some people think the human body odor is unpleasant to other animals. On the other hand, it may be that man-eating lions died from wounds made by the sharp sticks and rocks of the near-humans. An attacking lion could make a kill but die himself in the process.

If we could look back and see these near-humans as they were, we would see ape-like heads and faces on human bodies (Figure 37-3). Were the bodies hairy? Probably so, but we really do not know. Behavior would be partly human and partly animal. There would be shouts and calls, but no real language. The young would watch the older ones to learn toolmaking and other useful tricks.

Early man. These near-humans must have lived more or less unchanged for many millions of years. Then, about a million years ago, one group evolved

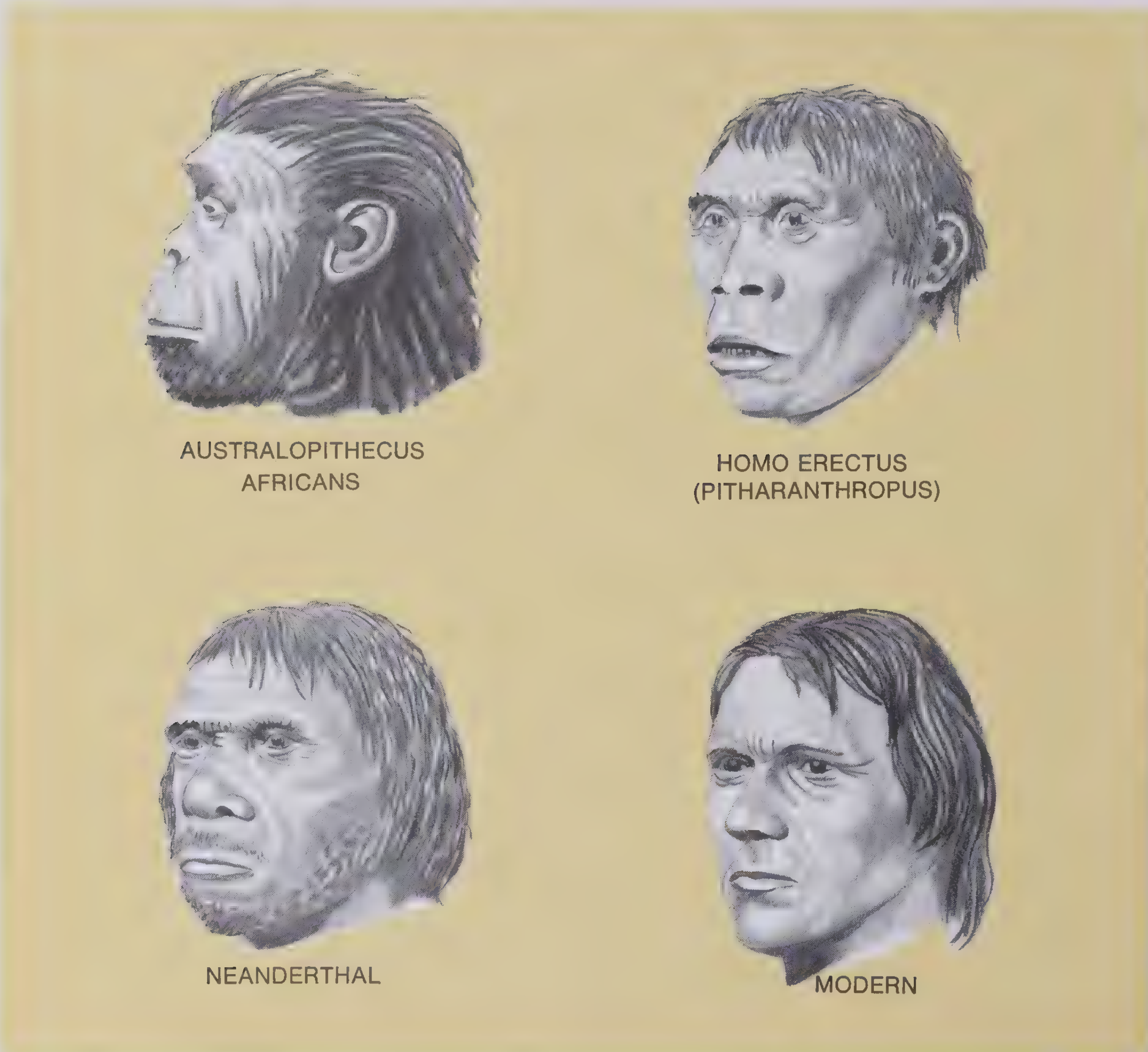


Fig. 37-3. An artist's idea of the faces of four of the types shown in Fig. 37-2. Of course we do not really know such things as how hairy they were or how dark their skin was.

quite rapidly to become man. This early type of man is called *Homo erectus*. Remember that modern man is called *Homo sapiens*.

The first fossils of *Homo erectus* show us a man with a body like ours and a primitive human face. The jaws were heavy, the chin rounded, and there was a heavy ridge above the eyes. The forehead sloped back over a brain of medium size—its volume about halfway between that of modern man and the larger apes. This brain had become bigger in the places where our centers for speech are located. Probably these early men talked. This means that they could plan things together. They could teach their children. They could depend on learning to find ways to survive and

could change their ways of doing things.

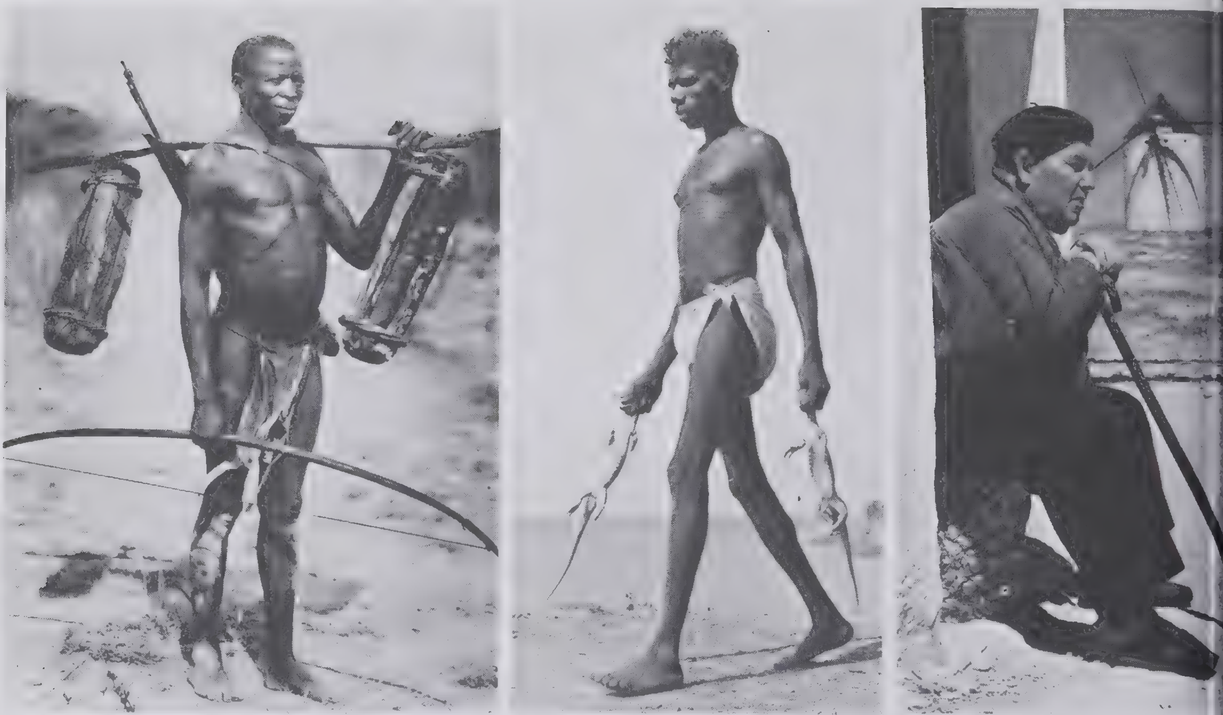
As always, it was a change in the environment that brought about this new development. Early man was a hunter of big game. He made weapons good enough to kill large animals, thus opening up a whole new food supply. Those who were bright enough to learn the new tricks might live to hunt another day. Any new mutation toward higher intelligence was a help toward survival. The old near-human genes for lower intelligence were a disadvantage. But again, it took a great deal of dying to eliminate the old genes.

Language was especially important. Big game animals were hard to kill with primitive weapons. Many men had to cooperate in the hunt. Language made it possible to do the planning. The men could then hunt as a team. They could learn to work and live together.

Fig. 37-4. These baboons are a type of primate that live on the ground. This is the environment where man's ancestors are believed to have lived. (W. Suschitzky)

Human cultures gradually came into existence. The *culture* of a group of people is their total set of ideas, knowledge, and ways of doing things. Different cultures can be developed in different places to meet local situations. This gave early man a great advantage over all other animals. He spread out over all of Africa, Europe, China, and southeast Asia, but never reached America or Australia. What do you suppose happened when a band of these early hunters came across some of the old type of near-humans who still survived? We do not know, but in any case the last of the near-humans finally disappeared.

Modern man. Early man continued to develop. Finally, about 500,000 years ago, some of these individuals developed large enough brains to be called modern man—*Homo sapiens*. Other groups remained more primitive. It was not until 30,000 years ago that the last men of the *Homo erectus* type died out. A very famous early form of *Homo sapiens* was the group known as Neanderthal man (Figures 37-2 and 3). The Neanderthal type lived over a wide area of Europe, Asia, and Africa from about 100,000 years ago until about 30,000 years ago. If he were alive today we would undoubtedly call him a race of modern man. Not all scientists agree, but probably the present form of man evolved from some group of Neanderthals. Neanderthal man had some of the facial appearance of early man, and his brain was different than ours. It was lower, but longer.



A B C

Modern man *(Homo sapiens)* has now spread out over all of Africa, Europe, Asia, Australia, and the Americas. He has developed cultures that enable him to live all the way from the tropics to the Arctic and from the rain forests to the deserts. As with any widespread species, the local populations have developed their own special gene pools. One group has more genes for curly hair. Another has more genes for straight hair, and so on. This makes the people of one population look somewhat different, on the average, from those of another population. We call these variations *racial differences*.

These racial differences are not great. People everywhere have about the same average intelligence, the same range in size and strength, the same basic human nature, and get much the same diseases. For any two races of man we can find some people with traits in between. It is hard to say where one race ends and another begins. There are many variations within all of the races and scientists really do not know how many "races" of man there are. The races developed when people were few and widely scattered. A mutation might take place in one group, but not in another. Natural selection would favor a gene in one environment, but not in another. So the racial types developed partly by accident, and partly as adaptations to different environments.

The main races of man today are those groups that happened to develop successful cultures. Their cultural advantage over other groups enabled them to spread over wide areas and to build up big populations. As we have noted, scientists do not always agree about the races of man. But six groups that are often described are listed here.

D E F G

Fig. 37-5. The main races of modern man. A. Capeoid (African bushman); B. Australoid (Australian aborigine); C. Caucasoid from Europe (Spain); D. Caucasoid from India; E. Negroid; F. old Mongoloid; G. new Mongoloid. (A. South African Information Service; B. Fritz Goro LIFE Magazine © Time Inc.; C. Spanish National Tourist Service; D. Government of India Tourist Office; E. UPI Photo; F. Sovfoto)

1. *Australoids*. These are the people who first lived in Australia. In their way of life many still live like Old Stone Age hunters, though some are now becoming cowboys or entering other modern occupations. They have heavy brow ridges, which remind us a little of early man. Their hair is wavy, and the men have heavy beards and hairy chests. Most have dark skin.

2. *Capoids*. These are the bushmen of South Africa. They are called Capoids after the Cape of Good Hope at the southern tip of Africa. Originally they occupied most of Africa south of the Sahara Desert. They are rather small people with yellowish skin, tightly curled hair, and narrow eye openings. They are primitive hunters, living in the Kalahari desert.

3. *Negroids*. The Negroids are thought to have first evolved on the open plains of West Africa south of the Sahara Desert. Most of their racial traits are explained as adaptations to the intense sunlight and heat of this environment. The dark skin does two things. It prevents sunburn. It also prevents too much vitamin D from being produced in the skin by sunlight.

Negroid people may often have long arms and legs and usually have very little fat under their skin. This was

probably an adaptation for exposing large areas to the air for cooling the body. The Negroids include the tallest and the shortest groups on earth (the Watusis and the Pygmies).

In the last few thousand years the Negroid people have spread out from their West African homeland. Some even reached islands in the South Pacific. Others went eastward and southward in Africa, driving the Capoids before them. Finally, during the last century, they met Europeans spreading northward from the Cape of Good Hope. The Capoids were caught in between. The few of them that are left now live in the desert, where no one else cares to go.

4. *Caucasoids*. This is the so called "white" race. It is not a very good term because actually many of the Caucasoids are dark. The Caucasoids are thought to have originated in southwestern Asia although the exact place is unknown. From this rather small area they spread out about 30,000 years ago, in much the same way that the Negroids did later. The Caucasoids went westward replacing Neanderthal types who still occupied Europe and North Africa. They went southeastward, occupying Persia and India. In southern India they seem to have mixed with earlier, Australoid types.

Caucasoids vary a good deal. They tend to have rather wavy hair, an average build, a fair amount of fat development under the skin, and large noses. They and the Australoids are the two hairiest races today.

The more northern Caucasoids are usually light skinned. Some also have blond hair. Tropical Caucasoids, like those in India, have brown skins. A dark skin there has the same advantage it has in Africa. The pale skin of Europeans may have some advantage in a northern climate because it lets in what little sunlight there is to produce vitamin D. Then again it may be just the loss of an unneeded trait. Sunburn is not such a deadly thing in the north. Mutations causing the skin to lose pigment do not matter, so they are not eliminated by natural selection. There only needs to be the ability to form some tan during the summer months.

5. *Old Mongoloids*. These are not a lot different from the Caucasoids. They may have somewhat darker skin color. Their hair is black, coarse, and straight. The inner corner of the eye tends to turn down slightly. These people originally spread over most of Asia and into Alaska. About twelve thousand years ago some of them got past the melting glaciers and occupied all of North and South America. They became the American Indians.

6. *New Mongoloids*. One group of Old Mongoloids became trapped north of the Himalaya Mountains during the last push of the Ice Age. They could not escape to a better climate because of mountains and other natural barriers. This is a region that, even today, gets down to 80 degrees below zero in the winter. Think how cold it would have been during the Ice Age! Many must have died. Those that lived developed adaptations to combat the cold. We recognize these traits today as racial characteristics. This race tends to have rather compact bodies with an evenly developed fat layer under the skin which holds in heat.

This fat covers the cheek bones, giving the face a flatter than average appearance. The insulation over the face reduces sinus infection. A fold extends downward over the upper eyelid (the Mongoloid fold). This gives the so called "slanting eyes." Of course the eyes do not really slant at all. The fold protects the eyelids from freezing.

When a warmer climate returned, the New Mongoloids spread out and occupied all of eastern and southeastern Asia. Koreans are probably the best example of the New Mongoloid type today. The Chinese and Japanese are mainly New Mongoloids. Other groups show more or less mixing with Old Mongoloids or with Caucasoids.

The New Mongoloids, like the Caucasoids, show a range of skin color. Northern Chinese are as light as many Europeans. Some tropical groups have brown skins.

Races today. The racial types get less and less clear cut as time goes on. In Europe, for instance, there were repeated invasions by Mongoloids. Their genes are still there, mixed in with the local, Caucasoid ones. Europeans also have a little Negroid ancestry. A good many Negroids were brought across the Sahara by the Carthagenians, Egyptians and Romans. Their genes are also still there, mixed with the Caucasoid ones.

Likewise, the Negroids did not always kill the Capoids they replaced. There was some mixing, and traces of Capoid traits can be seen in many Negroids. Arabs and Berbers of North Africa are Caucasoid types. There has been contact between them and the Negroids. Some Caucasoid traits are visible in some of the modern African tribes.

We have already shown how new and old Mongoloids are mixed in Asia. In America, Caucasoids, Negroids, and old Mongoloids are all present. Already the Negroes of America carry about 25 percent of Caucasoid genes, on the average. Many of the Indians also have some Caucasoid ancestry.

So, you see, "pure" races are a myth. All races today are mixed. The old advantages of the racial characteristics in special environments are no longer very important. A pale skinned Caucasoid can survive under the hot African sun by wearing a hat and light clothing. A Negroid can live in cold climates by eating vitamin D and wearing warm clothing. As a matter of fact, it was a Negro American who first set foot on the North Pole. This was Matt Henson. He was the best of the men Admiral Perry had with him when he crossed the ice to the pole. Henson was ahead, breaking trail, when they reached it. There they stood, on the floating sea ice, in that terrible environment. Men of three races were there—Mr. Henson (Negroid), Admiral Perry (Caucasoid), and four Eskimoes (New Mongoloid).

Characteristics of man. As we have seen, some of the outstanding traits of man are his high intelligence, his use of tools, and his use of language. He cooperates with other men in food-getting and defense. He develops cultures to fit local situations. Man's huge brain keeps working, even when his practical needs have been sat-

isfied. He is curious to know and to understand everything. Man still has the emotions and the need for excitement that made his ancestors such successful big game hunters. These traits push man to reach the poles, to climb mountains, to dive beneath the sea and to do scientific research. It still satisfies a basic need when he goes hunting and fishing.

Man's effect on the environment. Remember that man started out as a hunter. Ordinarily the traits of a hunter change slowly. Traits of the animals it feeds on change also. Their rate of reproduction, their protective coloring, their ways of hiding or running become adapted to meet the new danger. Things stay in balance.

But man can develop a new culture in just a few generations. There is not time for other species to evolve and to adjust to the new threat. Early hunters kept inventing newer and better ways of killing their prey, and they did not think about conservation. As early man spread over the earth, many big game animals gradually became extinct. The first Indians to enter America were very good hunters. In fact they were too good. They wiped out two species of elephants, the giant bison, and very likely some other types.

Later, man invented farming. This increased his food supply, and also increased the human population. The clearing of land for farming has changed the whole world environment. In Chapter 17 we saw how this affects both soil and wildlife. The other species of living things would need millions of years to adapt to such a drastic change. Long before that, man will change his ways again.

If we place bacteria in a jar of food material they grow very rapidly at first. Then, as their food supply is used up and their own wastes pile up, their growth slows down. finally, the food is gone, and the wastes poison the remaining bacteria. The population gets smaller and smaller and finally disappears.

In a balanced aquarium things are different. Green plants make food. Small animals use some of it. Animal wastes are used by plants to make more food. Bacteria break down plant and animal remains so they can be used again. The building up and breaking down processes are in balance, so they can go on and on. There is no accumulation of poisons. No one species gets everything, but all survive.

In recent years the human population has been increasing almost like the bacteria in the jar. There are more and more people to eat the limited food supply. You will see reports of serious famine in many countries during your lifetime. It is already too late to prevent this from happening. Also, like the bacteria, we are filling our environment with poisonous wastes. We call this *pollution*. Many people with lung trouble die each year from city smoke and smog. Many water supplies become useless. Gasoline engines pour carbon monoxide, hydrocarbons, and lead compounds into the air. All these materials are poisonous. Traces of these lead compounds have been found settling on the snow in central Greenland! DDT has been found in Antarctica. We are not filling just one little jar with poison. We are filling the whole world—our entire living space!

Fig. 37-6. How many kinds of pollution are present in the photograph of a city? How do overpopulation and pollution endanger such places as a river where fisherman try their skill? (National Air Pollution Control Administration; Vermont Development Department Photo)

Obviously this cannot continue. Only a *balanced community* can survive. We need to organize our world like the balanced aquarium instead of the bacterial culture. A balanced world community cannot have too many people in it, so the limiting of population is one problem facing man. In former days over half the children died before they grew up. Disease and the dangers of life killed adults at a higher rate than now. No one worried much about overpopulation. But now nearly everyone grows up. No wonder the population is increasing!

The high death rate of past times did more than limit populations. It eliminated undesirable genes. Those who carried harmful mutations were more likely to die young. They could not reproduce and give their faulty genes to the next generation. Today our doctors save most babies, and the harmful genes are accumulating.

War is still another problem. There has always been competition between the people of different cultures. Men in one group think, act, and dress differently from those in other groups. Often they think of these other people almost as if they were a different species, like wolves or bears. The wars fought between tribes many years ago were not big ones. They were a series of small battles fought now and then. But these little fights added up. Remember how Caucasoids completely replaced Neanderthals in Europe and how the Negroids and New Mongoloids also over-ran huge territories.

In each of these cases, there was always someone left. *Man* as a species survived even though many individual *men* died.

A modern atomic war would be quite different. The world environment would be badly polluted with radioactive fallout. Those who were not killed might carry great numbers of harmful mutations in their chromo-

Fig. 37-7. What sort of world environment will be built by today's children? (United Press International Photo)

somes. It would take a very high death-rate for many generations to eliminate these mutations.

Man and biology. See, then, how many of man's serious problems involve biology. Let us list them:

1. Conservation
2. Overpopulation
3. Pollution
4. Unbalanced world environment
5. The buildup of harmful mutations
6. The biological damage of atomic war

How many of our leaders understand the biology that is needed to meet these problems? You are a citizen of the world environment. You can, at least, do your part toward getting man in balance with the rest of the living world. As an understanding citizen you can let your leaders know that you expect them to face the problems and find answers that will make things better, rather than worse. In other words, it is time that man used his big brain for understanding his place as a species in a living community.

CHECK YOUR FACTS

1. **Name several types of primates.**
2. **What new environment led to the development of the upright body and the walking type of feet and legs found in man?**
3. **What unusual method did the early near-humans use to help them survive in their dangerous environment?**
4. **What new way of life led to the development of modern man?**
5. **What were the main differences between the near-humans, early man, and modern man?**
6. **Why are there different races of modern man? What are the main racial types?**
7. **Is man in balance with his environment? Give reasons for your answer.**

UNIT 6 SUMMARY

Sponges are many-celled, simple animals. A sponge has division of labor among its cells. Its body wall has many pores leading to the inside of the animal. Sponges are filter feeders, taking bits of food from the water which they pump through their bodies. Feeding cells, which line the hollow body, take in the food and digest it. The sponge skeleton is a simple framework that stiffens the body.

Hydra is a member of the coelenterate phylum. It lives in fresh water. It has two cell layers and an inside cavity with only one opening. *Hydra* has tentacles armed with stinging cells that are used to capture food. Corals, jellyfish, and sea anemones are other members of this phylum. Corals are well represented in the warmer seas. They form large colonies that are supported by lime skele-

tons. Coral skeletons, together with skeletons of algae and sponges often form reefs—sometimes of great size.

Many flatworms are parasites. But *Planaria* is a flatworm that lives its own life in ponds and streams. *Planaria* has a number of organs and systems. Tapeworms and flukes are flatworms that are parasitic on larger animals and man. Many of these parasites need two hosts to complete their life cycles. The young tapeworms form cysts in the muscle tissues of the alternate hosts.

Various roundworms are also parasites. They are not divided into segments. They have an intestine, with a mouth at one end, and an anus at the other. Many species of plants and animals are attacked by roundworms. Some roundworms are parasitic on man—among them are *Ascaris,* hookworm, and the trichina worm.

The earthworms and their relatives are segmented. They have several body systems and are a good deal more complex than the flatworms or the roundworms. Some segmented worms live in the soil, some live in fresh water, while others live in the sea.

Mollusks include clams, oysters, snails, squids, and octupuses. The basic body parts are the foot, mantle, mantle cavity, gills, body, and head. Most of them have shells. Different types are adapted to various ways of life. Clams are filter feeders, snails scrape food from the surface, and squids hunt other animals.

The arthropods make up another phylum. They are the most numerous animals. They have an outer skeleton, segmented bodies, and jointed appendages. Various arthropods live on land, in the air, in the soil, and in the water. Crustaceans are one class of arthropods. They include such animals as lobsters, crabs, crayfish, and shrimp. Other smaller crustaceans are important members of food chains. Spiders, ticks, scorpions, centipedes, and millipedes are other types of arthropods.

The insects are the most important class of arthropods. The body of an insect is divided into a head, chest, and abdomen. An insect usually has six legs. Some have four wings while others have only two and still others have none at all. Some insects have chewing mouthparts and others have mouthparts which are adapted for sucking.

A young grasshopper looks much like an adult, but it has no wings or sex organs. Moths are different. They produce a larva not at all like the adult. The larva feeds, grows, and becomes a pupa. While the insect is in its pupal case, it changes into an adult moth.

Some insects are useful to us. We get honey from bees. Bees and other insects carry pollen from one plant to another. Some useful insects eat other insects that are pests. But many insects attack crop plants or other materials we use. These insects are successful competitors of man.

Starfish belong to a phylum of animals that live only in the sea. Other members of the group are the sea urchins, sea cucumbers and sea lilies. Starfishes and their relatives have tube feet attached to a system of inside water canals. These tube feet are used to hold on to objects in the water and also to move from place to place. Many members of this group have hard plates in their body walls, from which spines may project.

The vertebrates are higher animals with backbones. They include three classes of fish known as the lampreys, the sharks, and the bony fishes. They also include the amphibians, the reptiles, the birds, and the mammals. Only the birds and mammals are warm-blooded.

The amphibians are the frogs, toads, and salamanders. Many of them spend part of their lives on land. Almost all of them return to the water to lay their eggs. Amphibians descended from fish millions of years ago.

The reptile class includes turtles, snakes, lizards, crocodiles, and alligators. They all have outer coverings of scales. Their eggs can develop on land. During the Age of Reptiles, millions of years ago, giant dinosaurs roamed the land. Some were plant eaters, and some were flesh eaters. There also were many smaller species of dinosaurs, as well as other kinds of reptiles. All the dinosaurs became extinct long before our time. Reptiles are handicapped by being cold-blooded, and so must remain inactive during the winter season.

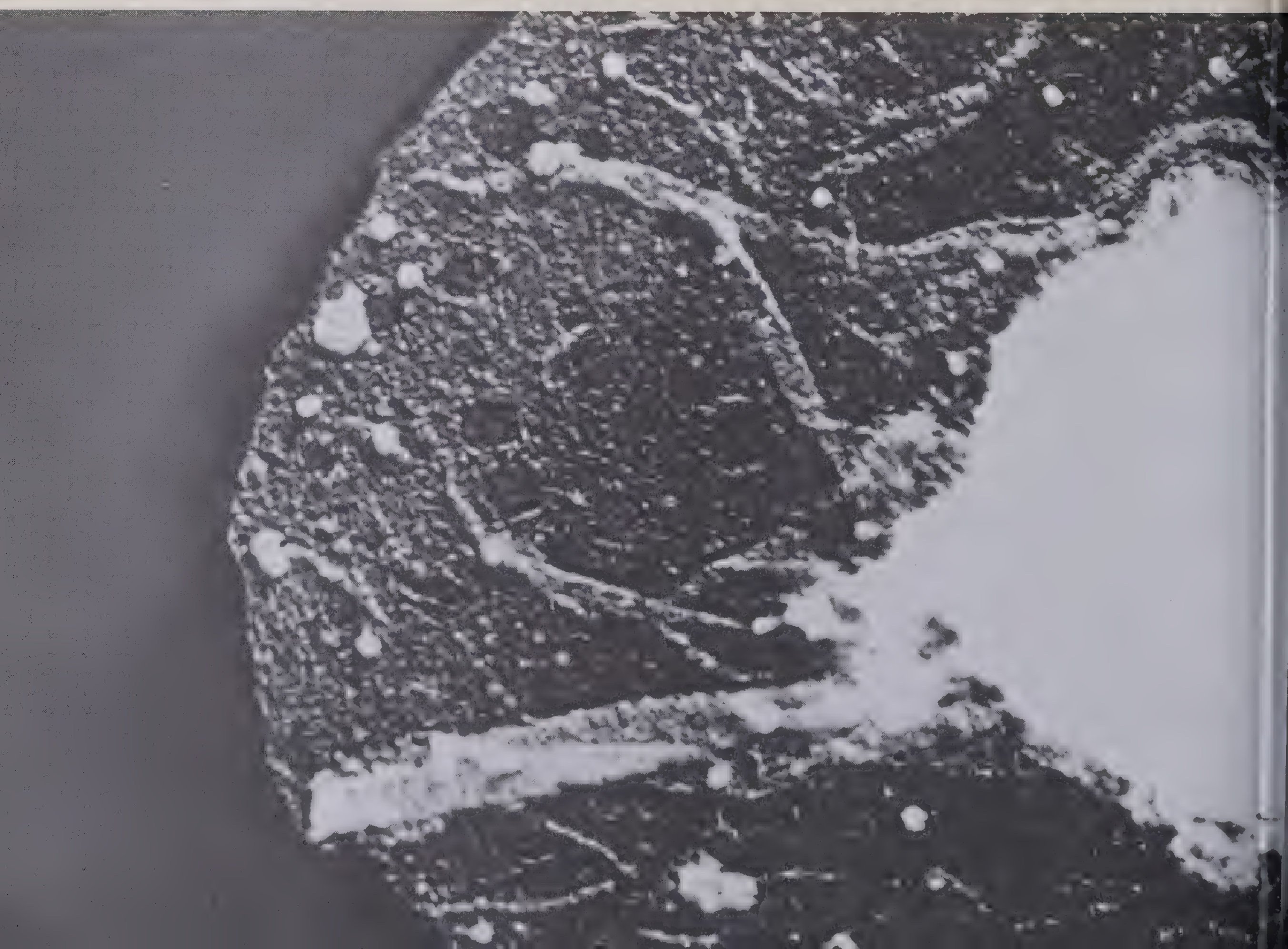
Most birds fly, and some migrate long distances. A bird skeleton is light and strong. Wings with their covering of feathers form a flight surface. Birds are warm-blooded, so their bodies can provide the large amount of energy that is necessary for flight. Most birds eat seeds or insects. They destroy large numbers of weed seeds and insect pests each year. Among the exceptions are hawks and owls that feed largely on rats and mice.

The mammals are another group of warm-blooded vertebrates. Mammals have an outer covering of hair. Female mammals develop milk glands. Mammals first appeared during the Age of Reptiles. Most of the early types were small. But the group expanded greatly as soon as the reptiles began to decline. Today, we find mammals on the land, in fresh water, in the sea, and even in the air.

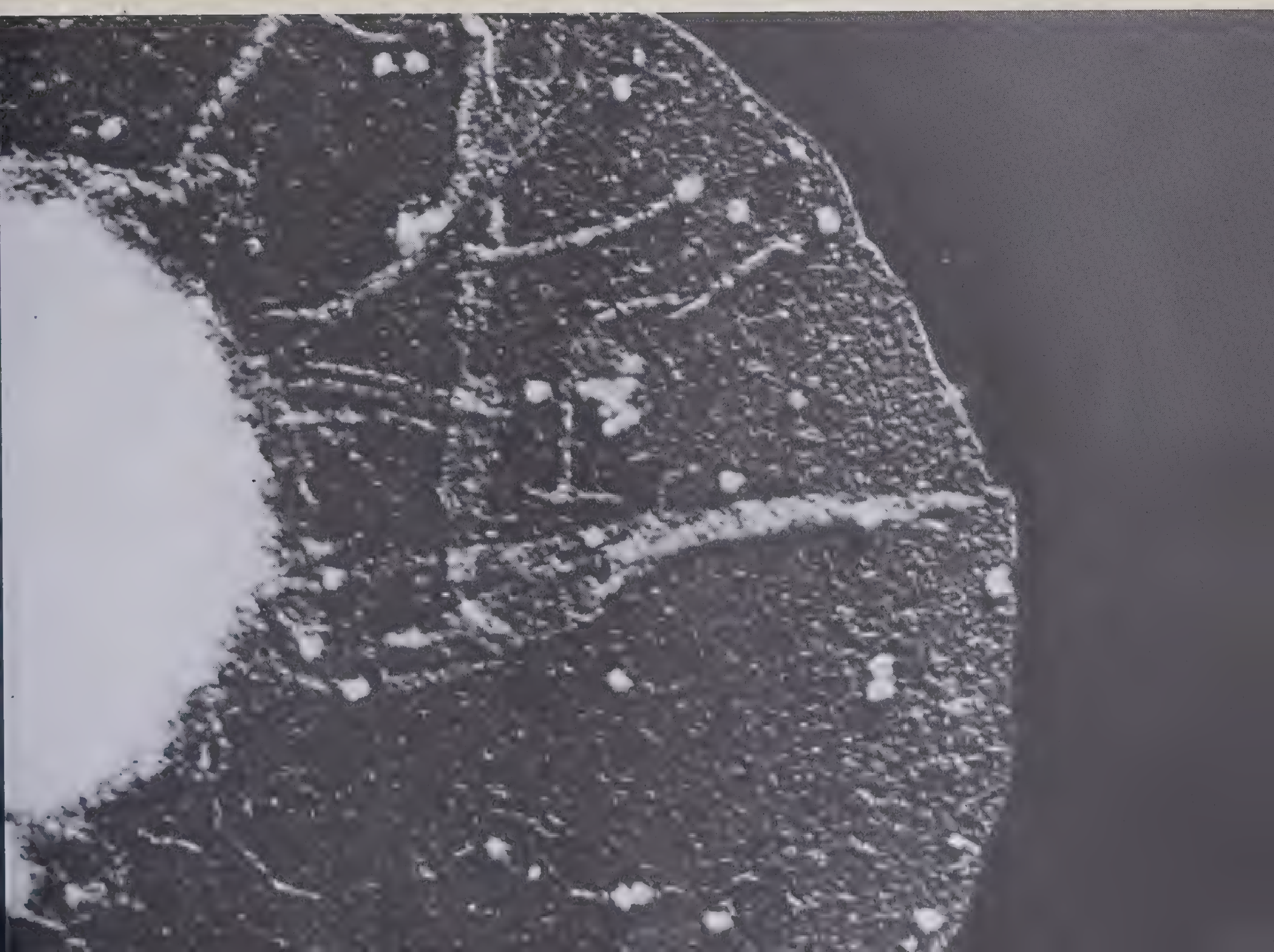
Man is a member of the primate order of mammals. He developed from more primitive types a long time ago. His actions are learned from other members of his cultural group. Man is not in balance with his environment. With his reasoning ability he may realize this in time to make needed changes in his relationship to the earth and to other species on the earth.

UNIT 7

Human Biology



This unit is about your own body. First, we shall learn some things about the foods we eat. Then we shall study the various body systems and learn something about what they do. Finally, we shall take up the special and important problems of disease and harmful drugs. This is a very practical study and will help you to take care of your own body properly. You will, at the same time, be learning more about biology because biology is partly about man himself.



CHAPTER 38

Food

Our study of the vertebrates in the last four chapters did not include much about the structure and function of their body systems. Now is the time to make such a study. Man is a vertebrate who is very interesting to us, so we shall use him as our example. In the next eight chapters you will learn about the human body. Of course, we cannot use the human body for laboratory dissection, so in Chapter 47 we shall sum up everything, using the frog as our example.

Before we study the body itself, we ought to learn about food. Food is the source of materials for the building of protoplasm in our bodies. It also furnishes the energy needed to do the work of the body (Chapters 4, 5, 6). Some foods even serve to regulate the chemical changes going on in the body.

This study of foods is a very practical topic for you. You will go on eating all your life. The kind of food you eat will have a great deal to do with your future health. It can even influence how long you will live. If you are a girl, you will probably be choosing and preparing the food for a whole family in just a few years. The health of the family will depend partly on how well you understand foods.

The energy needs of the body. As you know, certain food molecules in protoplasm combine with oxygen and yield energy. In studying foods, we need a unit for measuring quantities of energy. Such a unit makes it possible to compare the energy value of one food with that of another. The unit of energy we use is called a ***Calorie.*** The Calorie is really a unit of heat, but in studying food you may think of it as a measure of energy in general.

The energy we need is obtained from the Calories in the food we eat. Different people require different amounts of Calories. The following things affect the energy needs of the body:

1. *Size.* Naturally, a large person uses more energy than a small one and therefore needs more food.

2. *Age.* As we become older, our bodies use less energy.

3. *Activity.* Physical work requires energy.

4. *Sex.* Pound for pound, men use more energy than women.

5. *Rate of growth.* Building new protoplasm is a process that uses energy. Young people who are growing need extra food, both to supply materials for growth and to supply energy to build protoplasm.

6. *Individual differences.* The basic

rate at which the body uses energy is not the same in all people.

7. *Efficiency of the digestive system.* Some people do not digest and absorb their food as completely as others. These people need to eat more food to supply the energy needs of the body.

You can see that the number of Calories needed by a person is an individual matter (see Table, below). The average 15 year old boy needs about 3,000. The average girl needs about 2,500. But you are not an average. You are a person. Your needs depend upon your age, size, activity, and so on. If you are neither fat nor very thin, if you are growing normally and feel well, you are probably receiving about the right amount of energy foods.

If a person takes in more energy foods per day than his body uses, the extra material is stored in the body as fat. If he takes in less than he uses, the body must oxidize materials already in storage. For adults, then, there is a very simple way to tell if they are eating the right amounts of energy food. If they begin to gain pounds over their normal weight, they are eating too much. If they begin to lose pounds from their normal weight, they are eating too little.

It is important not to get fat. Only one out of five fat men reaches the age of 70. Three out of five lean men live that long. A person should weigh about the same at the age of 55 as he weighed at 25. Yet if you think about the adults you know, you will realize that this is not what usually happens. Being overweight is our most common health problem. A person who is 50 pounds overweight is carrying 50 pounds extra baggage around with him all the time. Can you imagine carrying a 50-pound suitcase around with you all the time?

The best way to lose weight is to eat less. A person who tends to gain weight should learn to regulate his daily diet so that he does not take in more Calories than he needs. Although a person must eat fewer Calories to lose weight, he still needs other food values. One valuable thing

What Is Your Average Daily Food Need?

Type of Person	Calories per Day
Child under 2 years	1,000
Child 2 to 5 years	1,300
Child 6 to 9 years	1,700
Child 10 to 12, or woman not working	2,000
Girl 12 to 14, or woman doing light work	2,200
Boy 12 to 14, girl 15 to 16, or man not working	2,600
Boy 15 to 20, or man doing light work	3,000
Moderately active man	3,200
Farmer in busy season	3,500-4,500
Man at hard labor	4,000-5,000

you will learn in this chapter is to tell which foods are rich in Calories only. Some people damage their health by cutting down on all foods, instead of just those with a high Calorie value.

The energy foods. Carbohydrates, fats, and proteins all give energy to the body (Chapter 4). Proteins, especially, are important in building protoplasm. You may think of carbohydrates and fats as being mainly energy foods.

Carbohydrates are cheap sources of energy. We depend on the starch in potatoes, bread, and cereals to give us most of our Calories. These substances also contain some other food values such as minerals, vitamins, and proteins. It is important not to waste those extra values by careless food handling. Many of the vitamins in potatoes are just under the skin. When some people peel potatoes the peelings are quite thick. Then the potato vitamins go into the garbage. Vitamins and minerals in wheat are mostly in the seed coats. Milling wheat to make white flour removes seed coats. This is why whole wheat bread has more food value than white bread. Enriched white bread has had most of these lost food substances added artificially to make it about equal to the whole wheat type.

Breakfast cereals are made from the same grains as bread. They have the same general food values bread has. Whole grain cereals are better for you than other kinds. Wheat and oats have more all-round value than rice or corn, but the main thing to get

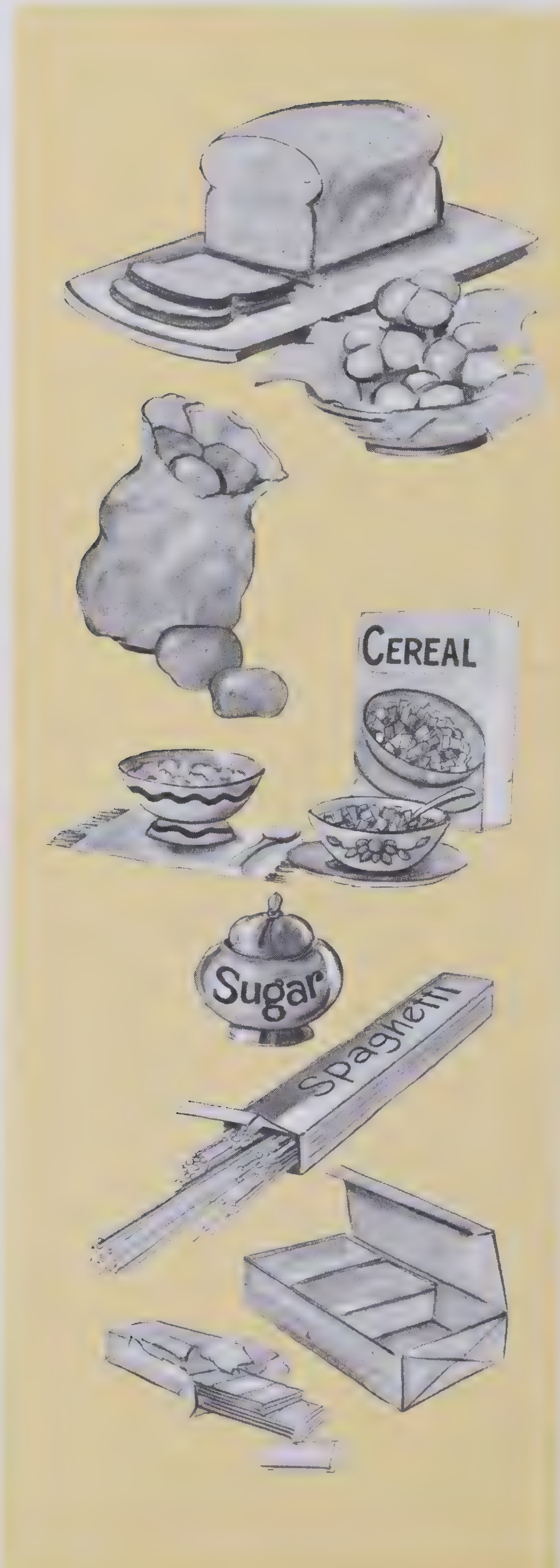


Fig. 38-1. Some of the everyday foods that are rich in carbohydrates. They are good sources of energy.

from any cereal is a cheap supply of energy. If a cereal is high priced, it is not worth the money. The expense of advertising breakfast cereals adds nothing to their food value. It only adds to their cost. The best money's worth in cereal is oatmeal.

Sugar is pure carbohydrate. It adds Calories and not much else to the diet. This is the big objection to eating too much sugar. If you eat sweets, they may satisfy your appetite, but you will not be getting the other food values your body needs. People with a weight problem should not eat sweet, fattening foods such as candy, cake, and pie. For those who need the Calories, these foods are all right as an extra treat.

Proteins are the most important materials in protoplasm. Protein foods are builders of protoplasm. Our bodies can also oxidize proteins for energy, but this is wasteful. We can easily obtain our energy from the cheaper carbohydrates.

The best sources of proteins are animal products such as meat, fish, eggs, and milk. Dried beans, peas, and nuts also contain proteins, but they are not as useful to the body as the animal proteins. Beans should not be used as a substitute for animal proteins more than about twice a week. Meat very often costs more than all of the rest of a meal. You might wonder how a family with a limited income can get enough good protein but there are some very good bargains in proteins.

Lean meat from any part of the animal is equal in food value. You do not

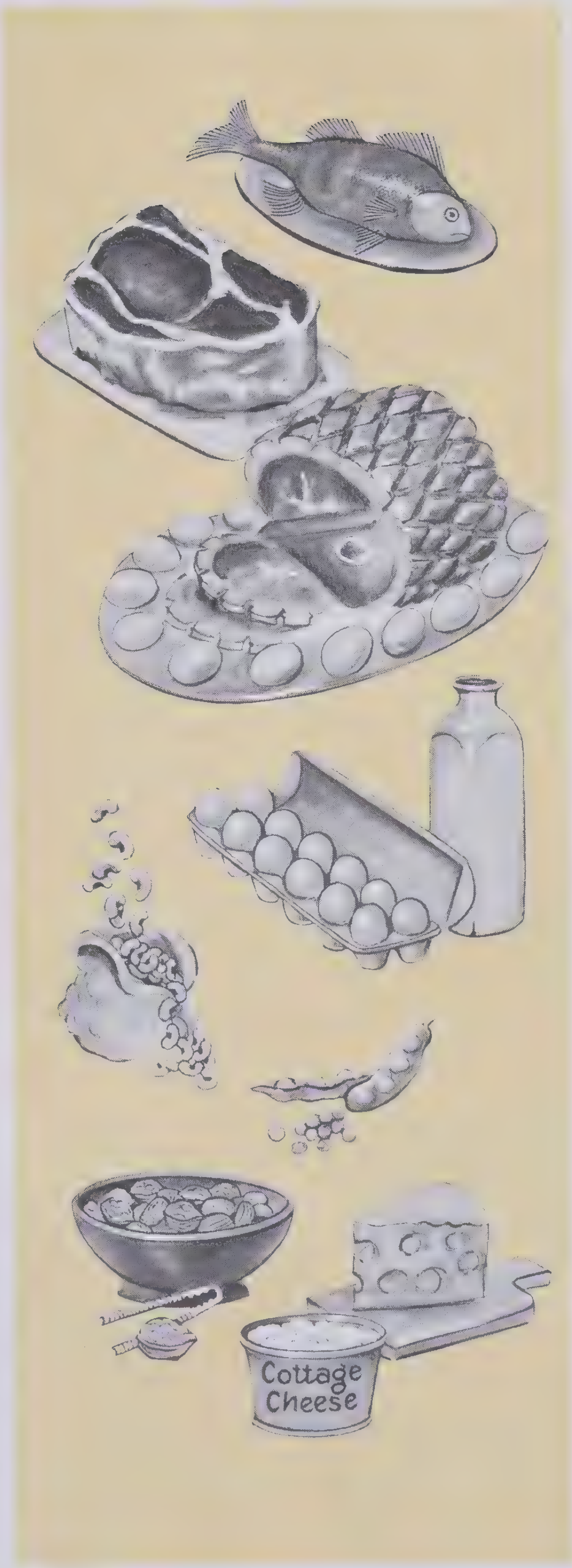


Fig. 38-2. Some of the everyday foods that are rich in protein. They help build protoplasm. These same foods are also rich in B vitamins and several others, as well.

have to eat steak to be well fed. A good cook can make any cut taste good. Some of the best buys in meat are brains, tongue, heart, kidney, frying chicken, pork liver, and frozen cod. Because so many people think they do not like these foods the prices are low. Actually, many of them are better for you than steaks and roasts. The animal stores extra vitamins and minerals in some of its organs. A family which learns to like these foods and eats them often, will be able to save hundreds of dollars a year.

Another big bargain in protein is cottage cheese. It gives more high quality protein per dollar than most other foods. Cottage cheese can be eaten frequently instead of meat. Eggs vary in price, but their food value per dollar is generally very high. Milk is a medium priced protein source. Powdered milk is a real bargain.

Fats are very concentrated energy foods. Pound for pound they give over twice the Calories that carbohydrates do. We need some fat in our diet, but not a great deal. Like sugar, too much fat adds too many Calories for the amount of other food values obtained. There is some evidence that large amounts of animal fat in the diet lead to heart and artery trouble. According to this theory, the liquid oils like olive oil, cottonseed oil, and corn oil are less harmful than the solid fats like butter, meat fats, lard and lard substitutes.

It is easy to recognize many fatty foods because of the way they look and feel. Most of them make grease spots on paper. You do not have to plan to include fats in your diet. The oils used in cooking and the butter or margarine used as flavoring will probably give you more fats than your body needs.

The minerals. Besides the energy foods, our bodies need a number of mineral compounds. We get some of these from drinking water, but most of them come to us in the foods we eat. There are over a dozen different elements that the body must have in the form of minerals. It will be worth your while to remember three of them.

There is enough ***iron*** in your body to make a medium-sized nail. Some iron is present in the compound which makes blood red. This red substance carries oxygen around the body. There are other iron compounds in your cells. They help in the handling of oxygen during respiration. If the iron should suddenly disappear from your body, you would die. Your body would suffocate because it had no oxygen.

The very best source of iron is liver. One small serving gives all the iron you need for a day. Other good sources are eggs, meat, and green vegetables. Milk does not contain iron. Sometimes babies have become sick by the time they were a year old because they were fed on nothing but milk. Parents should ask their doctors about the best food to feed their babies.

Calcium and ***phosphorus*** are two other important elements the body must have. These two elements combine with oxygen to make the hard material in bones and teeth. Calcium compounds are also important in blood. Protoplasm contains phosphorus. ATP, the energy carrier of the cell, is a phosphorus compound. So is DNA that the genes are made of.

The best source of calcium and phosphorus is milk. Eggs, cabbage, oran-

ges, and several other foods also contain calcium. So do eggs, meat, whole grain cereals, and some garden vegetables.

In general, fruits, vegetables, milk, and meats are high in mineral value. Again, you see why it is dangerous to fill up on starchy and sweet foods. They give you Calories, but they fail to supply the other food needs.

The vitamins. The ***vitamins*** are compounds produced in plants and sometimes in animals. We need them only in very small amounts. A few ten-thousandths of an ounce per day is all you need of most vitamins. Yet without them you would become very sick. When a person gets sick for lack of a vitamin we say he has a ***deficiency*** (dee-*fish*-en-see) ***disease.*** *Deficiency* means a lack of something.

Many vitamins are known to be needed by the human body. The list on the following pages gives some of the more important ones.

1. ***Vitamin A.*** This vitamin is needed for health of the tissues lining the throat and eyelids. It is also needed for normal night vision. A lack of vitamin A produces night blindness, a condition in which the person sees poorly in dim light. This has caused some serious accidents at night. Vitamin-A deficiency may also reduce resistance to colds and other throat infections. A continued shortage of the vitamin causes very serious eye trouble which finally may result in blindness.

Vitamin A is found in liver and kidneys, whole milk, butter, eggs, tomatoes, and nearly all green and yellow vegetables. The body can store it, so extra amounts eaten at one time can be used later.

2. ***Vitamin*** B_1 [also called *thiamin (thy-*a-min*)*]. This vitamin helps to control the oxidation of glucose in the cells. As you know, oxidation is the process that releases energy, so that a lack of vitamin B_1 is very serious.

Fig. 38-3. We learn a great deal about the effects of food by experimenting with animal feeding. Here, the rat on the left has a typical eye condition produced by a lack of vitamin A in its diet. On the right, the same rat has normal eyes as a result of using foods containing a rich supply of vitamin A. (Squibb Division—Olin)

A person who does not get enough feels tired out. If he gets still less the result is a serious deficiency disease called ***beriberi*** *(behr-*ee-*behr-*ee*)*. This disease is a serious problem in Asia, where an enormous amount of polished rice is eaten. Brown rice has just enough vitamin B_1 in its seed coats to prevent beriberi. When the seed coats are polished off to make the rice white, the vitamin is lost.

We polish our wheat to make white bread, just as the Asians polish rice to make white rice. But many Asians eat almost nothing but rice. We eat a lot of things in addition to bread. These other foods bring us minerals and vitamins that are lost when wheat is milled.

All whole grain foods contain some vitamin B_1. Vitamin B_1 is also found in meats, fish, milk, and most vegetables. You might think that anyone would get enough of this vitamin. Most of us do buy enough of the foods containing it. But vitamin B_1 is damaged by heat. Long cooking destroys much of it. Also, it is soluble in water. If you boil vegetables and throw away the cooking water, you are throwing away many of the vitamins and minerals. It is important to cook with as little water as possible and to feed the cooking water to the family. It may be included in soups or gravies.

3. ***Vitamin B_2*** or ***G*** [also called *riboflavin (ry-*boh-flay-vin)]. This vitamin is needed for normal respiration to continue in the tissues. A lack of it results in many serious conditions, such as stunted growth, scaly, sore skin, and eye disease. If a pregnant woman does not get enough riboflavin, her child will have a lower intelligence than it would have otherwise. This effect will be permanent. Sources of riboflavin are about the same as for B_1.

4. ***Niacin*** *(ny-*a-sin*)*. This vitamin is needed for proper use of carbohydrates in the body. It is found in animal protein foods and in many vegetables. A lack of niacin is the main cause of a deficiency disease called ***pellagra*** (peh-*lag*-ra).

Pellagra has been a problem in some parts of the United States. It appeared among poor farmers and mill hands of the South, where corn, molasses, and fat pork were often the main diet. These foods are very poor in protein, and they lack niacin almost entirely. Pellagra produces a skin rash, upset stomach, paralysis, and mental disturbance. One method of combating pellagra has been to teach people to grow their own garden vegetables. Adding niacin to the cornmeal sold in stores has also helped.

5. ***Vitamin C*** [also called *ascorbic* (as-*kor*-bik) *acid*]. This vitamin is needed to bind cells together. A lack of it causes tissues to break down.

Some vitamin C is found in most fruits. The best sources are oranges, limes, grapefruits, tomatoes, strawberries, green peppers, cabbages, lettuce, and other salad greens. When these foods are eaten raw their cells are still alive. Vitamin C keeps well in these living cells. When we cook such foods, the vitamin molecules escape through the cell membranes and come in contact with the air. Oxygen destroys vitamin C. If you squeeze an orange, drink the juice promptly. Do not leave it sitting around in the air. If you must keep it awhile, put it in the refrigerator. Oxidation is slower at a low temperature. Canning and

freezing preserves vitamin C, but the food should be eaten promptly after opening the can or after thawing the frozen fruit.

Serious vitamin C deficiency results in the disease called ***scurvy.*** Scurvy produces painful swelling of the tongue, blackened lips, bleeding gums, and sometimes loss of teeth. It was once common among sailors in the days of sailing ships. Canning had not yet been invented, and there was no way to preserve fresh fruits or vegetables on long voyages.

6. ***Vitamin D.*** We produce this vitamin in our skin, with the aid of sunshine. You may wonder how we can produce it in the winter, when the sun is low in the sky and our bodies are covered with heavy clothing. Actually, vitamin D, like A, can be stored in the body. We usually produce enough of it in the summer to fill our needs during the winter. Vitamin D is needed to make possible the deposit of calcium in bones and teeth. Children must have more vitamin D than adults because they are forming new bones. When a child does not have enough vitamin D, a disease called *rickets* develops. This disease was once common in northern lands. Fewer children have rickets today because most of the milk sold has vitamin D added to it. Also, babies are usually given fish liver oils. These fish oils are especially rich in vitamin D.

There are many other minerals and vitamins, but you do not need to learn them all. If you eat foods that give you the ones you have studied, the others will be there also. We shall now try to add up all our knowledge of foods and see what makes a good all-around diet.

A balanced diet. A balanced diet is one that gives the body everything it needs in the right amounts. We often divide foods into a number of groups and tell people to eat some of each group every day. This is a simple way to teach good food selection. The following is such a list.

1. The *milk group.* Young people should have a quart of milk a day. Other dairy foods include cheese and ice cream. A serving of ice cream or cheese may occasionally take the place of milk.

Some adults lose their ability to digest milk. It actually upsets their digestive systems. This is hereditary and is most common among people of the New Mongoloid race. Obviously such persons have to get along without milk in their diets.

2. The *meat group.* Two or more servings of meat, fowl, eggs, or seafood should be eaten daily. Dried beans, peas, and nuts may be substituted occasionally.

3. The *bread-cereal* group. This group includes whole grain or enriched bread or cereals, macaroni, and spaghetti. You should have two or more servings from this group every day.

4. The *vegetable-fruit group.* You should have four or more servings from this group every day. At least one serving should be oranges, grapefruits, tomatoes, berries, or salad greens. One serving should be a dark-green or deep-yellow vegetable, such as spinach (green) or carrots (yellow).

If you have understood everything in the chapter so far, you can explain which food values are represented in each of these groups. You will also see places where one food can be substi-

Fig. 38-4. Variety in choosing the menu is important. Eating some foods from each of these groups every day will give you at least some of every nutritional requirement needed for good health. (Grant Heilman)

tuted for another. For instance, if you eat more potatoes you will need less bread. You can eat cottage cheese instead of meat. Our modern knowledge of foods has already brought good results. Deficiency diseases are less common. There is less general illness. Young people are growing more rapidly and getting a little taller than their parents and grandparents. This is mostly due to improved diet.

Ideally, all three meals should be well balanced and about equal in size. This may surprise you. Perhaps you have been skipping breakfast. Breakfast is a very important meal. It gives the body energy to run on for the whole morning. Remember that you have not eaten for many hours when you wake up in the morning. There is no food in the intestine to be absorbed by the blood. Going without breakfast can weaken your resistance to disease, especially tuberculosis.

In planning your own diet, remember that you need more or less energy

Composition of Some Common Foods

			Percent of Average Adult Needs							
Food	*Serving*	*No. of Calories*	*Protein*	*Iron*	*Calcium*	*Vitamin A*	*Vitamin B_1*	*Vitamin B_2*	*Niacin*	*Vitamin C*
Apples	1 medium	78	.6	3.3	.8	2.4	3.3	2.2	1.3	8
Asparagus	1 cup	42	6.4	34.2	4.3	29	10.7	12.8	14	46.6
Baked beans	1 cup	325	21.7	45.8	14.6	1.8	8.7	5	8	9.3
Bananas	1 large	119	2.3	6.7	1.1	11.4	4	3.3	6.7	17.3
Bread	1 slice	63	2.9	3.3	1.8	0	4	2.2	3.3	0
Broccoli	1 cup	39	5.3	16.5	14.3	77	6.7	12.8	6.7	157
Butter	1 pat	50	0	0	.1	5.6	0	.04	.05	0
Cake (plain)	3″×3″×1″	180	4.9	1.7	8.5	1.4	1.3	2.8	1.3	0
Carrots	1 cup	71	1.7	12.5	5.4	590.4	4	2.7	5.3	8
Cauliflower	1/4 head	25	4.9	7.5	1.8	1.4	5.3	5	3.3	76
Cheese (cheddar)	1″×1″×1″	95	10	2.5	20.6	8	.7	6.2	.3	0
Cherries (sour)	1 cup	122	2.9	6.7	2.8	36.8	4.7	2.2	2.7	18.7
Chocolate (sweetened)	1 oz.	133	.9	6.7	1.8	.2	.7	2.2	1.3	0
Cookies	1 large	109	2.1	1.7	.6	0	.7	.6	.7	0
Corn	1 cup	170	7.3	10.8	1	10.4	4.7	7.2	16	18.7
Corn bread	2″×6″×1″	103	5	6.7	6.8	3	4.7	5	2.7	0
Corn flakes	1 cup	96	2.9	2.5	.3	0	.7	1.7	2.7	0
Cottage cheese	1/2 cup	107	30	3.3	10.8	.5	1.3	19.5	.7	0
Cream	1 oz.	106	3.7	.8	1.9	2.2		3.3		0
Doughnuts	One	213	4.7	6.7	2.7	1.6	9.3	6.1	.7	0
Eggs	One	77	8.7	10.8	2.6	11	40	7.2	.3	0
Fish	4 oz.	160	30	5	1.4	22	6.7	5.6	23.4	0
Frankfurter	One	117	9.1	5.8	.4	0	5.3	5	8	0
French dressing	1 tbsp.	59	.1	0	0	0	0	0	0	0
Green beans	1 cup	43	3.4	27.5	6.5	19.8	5.3	5.6	4.7	12.1
Hamburger	4 oz.	355	25.8	22.5	1	0	5.3	8.9	28.6	0
Ice cream	1 cup	290	8.1	1.2	17.5	14.8	4	15	.7	1.3
Jelly	1 tbsp.	50	0	1.2	.2	0	0	0	0	1.3
Lettuce	1/4 head	18	1.7	4.2	2.2	10.8	2.7	4.4	1.3	10.7
Liver (beef)	4 oz.	164	34.4	126.8	10.1	486.7	22.3	192	134.7	51.7
Mayonnaise	1 tbsp.	100	.3	1.2	.2	.6	0	0	0	0
Milk	1 cup	166	12.2	1.7	28.8	7.8	6	23.4	2	4
Oatmeal (cooked)	3/4 cup	80	4.9	7.5	1.1	0	8	1.7	1.3	0
Oranges	1 medium	62	2	5	5.1	5.6	8	2.2	2.7	103
Peanut butter	1 tbsp.	92	6	2.5	1.2	0	1.3	1.1	17.3	0
Pears	1 medium	85	1.6	4.2	2	.6	2	3.3	1.3	8
Peas (green)	1 cup	168	12.2	13.5	6.2	27	18.7	8.3	17.3	28
Pie (apple)	1 piece	266	4.1	15.8	1.1	0	3.3	2.2	2.7	0
Pineapple (crushed)	1 cup	303	1.4	13.3	7.5	4.2	13.3	2.2	2.7	30.6
Pop, soda	1 cup	75	0	0	0	0	0	0	0	0
Pork chop	4 oz.	334	26.8	23.3	1.1	0	64.6	12.2	32.6	0
Potatoes	1 cup	144	6	10	2	6	9.3	3.9	14	29.4
Round steak	4 oz.	207	31.7	27.5	1.2	0	6	10.8	35.4	0
Soda cracker	1 square	47	1.6	1.2	.2	0	.7	.6	.7	0
Sauerkraut	1 cup	39	3.7	10	8.5	1.6	5.3	8.3	2	50.6
Spinach	1 cup	45	7.6	30.4	2.9	315	2.7	12.8	5.3	45.4
Sugar	1 tbsp.	48	0	0	0	0	0	0	0	0
Sweet potato	1 cup	233	6.3	20.4	5.4	386	8	7.5	7.3	41.4
Tomatoes	1 medium	30	2.1	7.5	1.6	32.8	5.3	3.3	5.3	46.6
Wheat flakes (enriched)	1 cup	125	5.4	12.5	1.6	0	13.3	1.7	14.7	0

according to your age, sex, weight, and activity. In general, young people need more proteins, vitamins, and minerals than adults do. Remember that some food values will be lost if the food is improperly cooked.

ACTIVITY

Testing for sugar and starch. Place a pinch of glucose in a test tube. Fill the tube about two-thirds full of water and shake (with your thumb over the opening) until the sugar is dissolved. Mix equal amounts of Fehlings' solution A and Fehlings' solution B in another tube. Pour enough of this mixture into the first tube to color the water. Now heat the tube by setting it in a beaker of boiling water (direct heating in a flame is dangerous for beginners because of possible spattering of hot liquid). What color change do you notice? This is the test for simple sugars.

Place a pinch of corn starch in a test tube, add water, and shake. Add iodine solution one drop at a time. What color change do you see? This is a test for starch.

Crumble part of a white soda cracker into a test tube, add water, and shake. Test this food material for sugar. Prepare a second test tube with some crumbled cracker and test for starch.

In the same way test any other foods you wish. Which ones contain sugar? Which ones contain starch?

In some cases it will help to first cook the sample by boiling it a few minutes in a test tube. This will allow the iodine to enter the cells and reach the starch grains. It also will dissolve sugar out into the cooking water, so that it can be detected.

CHECK YOUR FACTS

1. **What are three things that food does for us?**
2. **What unit is used for measuring food energy?**
3. **About how many Calories do you need each day?**
4. **If we eat foods that contain more energy than we need what happens to the extra food?**
5. **What effect does being overweight have upon health? What is the best way to lose weight?**
6. **What is meant by the term, "balanced diet?"**
7. **Make a chart. In the first column list the following things: carbohydrates, fats, proteins, calcium, phosphorus, iron, vitamin A, vitamin B_1, vitamin B_2, niacin, vitamin C, vitamin D. In the next three columns show what each of these things does for the body, what happens if we do not get it, and several foods that supply it.**
8. **List all of the food you eat for one day. Then use the table on page 345 to help you figure out how many Calories you took in.**

Also figure how much of each of the other food values you received. (If some food you ate is not on the table look up some similar food and make a guess. Remember to make corrections for the amounts eaten. The serving you ate may be bigger or smaller than the amount given in the chart.) In what ways is your diet good? In what ways can it be improved?

CHAPTER 39

Digestion

You already know what digestion is. Solids cannot enter most body cells. It is the job of the digestive system to change solid foods into some dissolved form that protoplasm can use. Enzymes change all carbohydrates into simple sugars. Fats are broken down into fatty acids and glycerol. This is what they were made of in the first place. You will remember that proteins are made of amino acids. During digestion the bonds between the amino acids are broken, and they are separated from each other. It is these amino acid molecules that we absorb into our cells. There they are used to build our own body proteins.

The enzymes that do this digesting are contained in digestive juices, which are produced by several of the digestive organs.

The chewing of food. The digestive system starts working on food in the mouth, where chewing grinds it into smaller particles. Suppose that you could swallow a solid piece of meat two inches thick. Digestive juices could start working on it only at its outer surface. It would take a long time for the outside layers to dissolve so that enzymes could reach the center parts. When food is ground up, each little piece can be surrounded by digestive juices. Chewing greatly speeds up digestion. In any case, we must chew some foods before we can swallow them.

Your teeth. The job of breaking up food is performed by the teeth. There are four kinds of teeth. The front ones have sharp edges that cut off pieces of food. There are two of them in each quarter of the adult mouth. Right behind them is a strong, pointed tooth that can tear food too tough to bite off. Next come the chewing teeth—two light ones, and then three heavy grinders. This adds up to eight teeth in each quarter of the adult mouth. In all, an adult has 32 teeth (Fig. 39-1).

A small child needs teeth long before his mouth is big enough to hold 32 full-sized ones. First, he gets a set of 20 baby teeth. Later, as the jaws grow, each one is replaced by a permanent tooth. The heavy, adult grinding teeth come in behind the baby set. The last of these do not appear until a person is about 18 years old. These are often called "wisdom teeth."

Figure 39-1 also shows the structure of a tooth. The main body of the tooth is a hard, bone-like substance called ***dentine*** *(den-*teen*)*. The part of

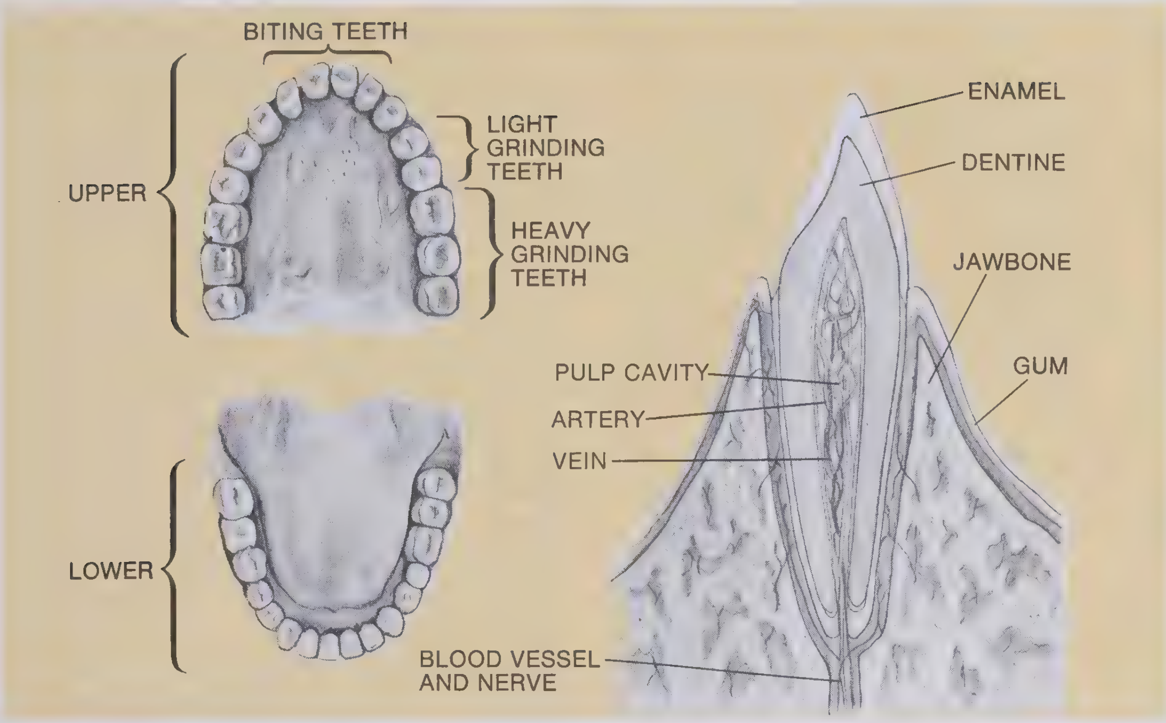


Fig. 39-1. The human teeth and their structure. Some other mammals have more teeth and some have fewer.

the tooth that shows is covered with an extra-hard white material, the ***enamel.*** The root of the tooth fits into a socket in the jawbone. A hollow space in the center (the pulp cavity) contains blood vessels and nerves.

Teeth begin to form in the jaw very early. Enamel for some of the permanent teeth is already forming before we are a year old. Good teeth cannot grow unless the child gets tooth-building foods which contain protein, calcium, phosphorus, vitamin C, and vitamin D. Even when good teeth have developed, they are in danger from tooth decay.

Tooth decay. It is not known exactly what causes tooth decay, but it is believed that sugar has something to do with it. The chemical situation that exists while sugar is in the mouth favors decay-producing bacteria. If people did not eat any sugar at all they would have far less tooth decay than they do now.

There are some things you can do to cut down on damage to your teeth. In the first place, limit the amount of candy and other sweet foods you eat. In the second place, limit the time that sugar is in the mouth. The longer you hold candy in your mouth, the more chance you are giving the sugar to do damage. Brushing your teeth soon after eating also helps to reduce the time of damage. You cannot brush your teeth when you eat away from home. But you can take a drink of water and rinse it through your teeth to wash away food particles.

At the present time few tooth pastes

will do much to prevent tooth decay. Brushing with plain water is almost as good. The fluorine treatment used by dentists reduces the amount of tooth decay, and fluorides added to tooth paste also help. Some cities add fluorides to the drinking water. This reduces tooth decay even more, but no method prevents all decay. If you visit your dentist often, he may find some decay before you know it is there. When you have a cavity in a tooth it should be filled right away. If you wait, the cavity just gets larger.

Saliva aids digestion. *Saliva* (sa-*ly*-va) is mixed with food during chewing. Saliva comes from three pairs of glands located in the sides of the face and under the jaw. These glands are masses of special cells. The saliva flows into the mouth through little tubes. Such a tube, which leads from a gland, is called a duct. One duct enters the mouth on the inside of each cheek. The other four ducts pour their saliva out under the tongue.

Saliva contains an enzyme which can digest starch. However, food is not in the mouth long enough for much digestion to take place, and saliva cannot continue to work very long in the stomach. But saliva does moisten food so it will not stick to the teeth and will slip down the throat during swallowing. Imagine trying to eat crackers with no moisture in the mouth!

The esophagus and stomach. When food is swallowed, it passes down the ***esophagus*** (eh-*sof*-a-gus). The esophagus is the tube leading from the throat to the stomach (Fig. 39-2). Food is pushed along as circular fibers of muscle tissue in the wall of the esophagus contract.

There are two parts of the body cavity in man and other mammals. There is the *chest cavity* and, below it, the *abdominal cavity*. These two parts of the body are separated by a tough, muscular partition called the ***diaphragm*** *(dy-*a-fram*)*. The main digestive organs are located in the abdominal cavity below the diaphragm.

The ***stomach*** is a pear-shaped, muscular sac. Its main function is to store food. If there were no such storage organ you could not eat a whole meal

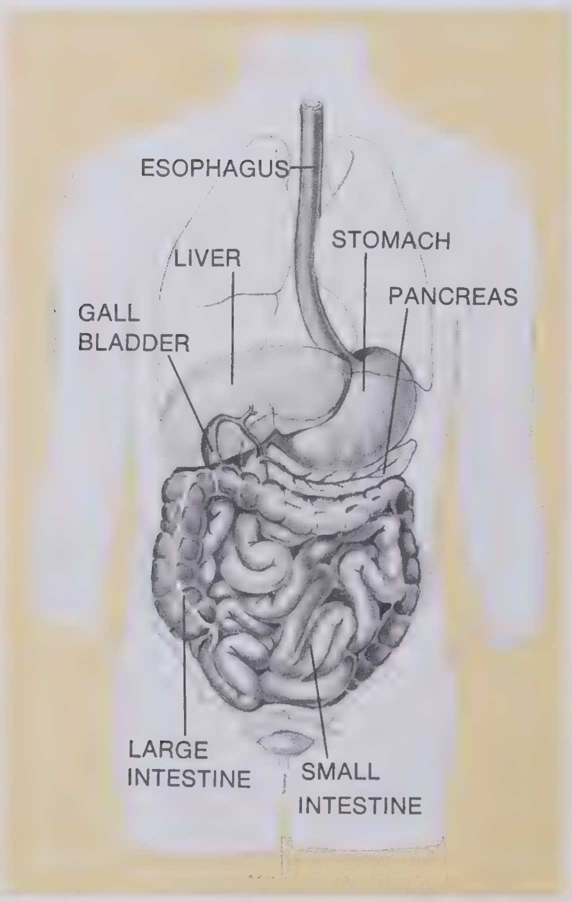


Fig. 39-2. Diagrams of the main organs of digestion. Trace the route of the food during digestion.

at one time. The stomach lining contains a great many tiny glands which pour out a clear yellow liquid that mixes with the food. This is the ***gastric juice.*** It contains an acid that softens fibers in the food and kills many bacteria. Gastric juice also contains an enzyme that acts on proteins.

Muscles in the stomach wall keep contracting and relaxing. This mixes the food with the gastric juice. The food particles break up into smaller and smaller pieces. The proteins become partly digested. The food passes into the small intestine, a little at a time. It takes about two hours for the stomach to empty itself completely.

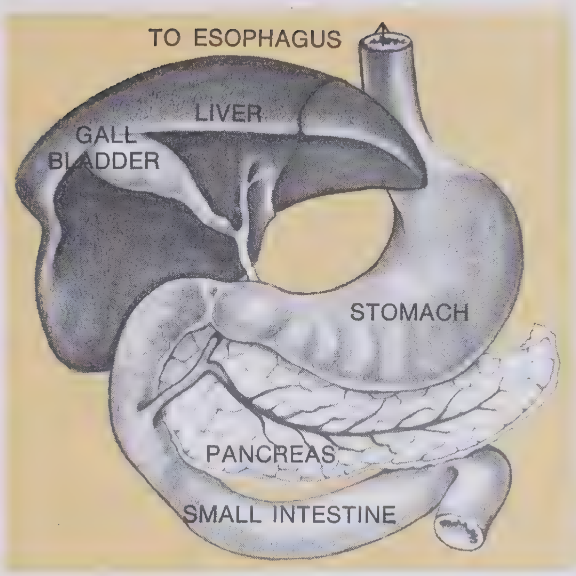


Fig. 39-3. The relationship between the liver, gall bladder, pancreas, stomach, and small intestine. The liver has been pulled upward, out of place.

Digestion and absorption in the small intestine. The small intestine is the main digestive organ. It is a tube about three-fourths of an inch across and about 22 feet long. The digesting food takes several hours to pass through it.

There are three juices that act on food while it is in the small intestine. ***Intestinal juice*** is produced by the intestine lining. ***Pancreatic*** (pan-kree-*at*-ik) ***juice*** flows in through a duct from an important gland lying near the stomach (Fig. 39-3). This gland is the ***pancreas*** (*pan*-kree-us). Its duct enters the small intestine near its upper end. A juice called ***bile*** also enters the intestine at this same place. Bile is produced by the liver.

The ***liver*** is a large, glandlike organ in the upper right side of the abdomen. It has several functions, besides producing bile. You will learn about them in other chapters. Bile is being formed in the liver all the time. It is stored in a sac called the ***gall bladder.*** When food leaves the stomach the gall bladder empties its bile through a bile duct. The bile duct and pancreatic duct come together as they reach the small intestine. Their juices enter it together.

Pancreatic juice and intestinal juice contain several enzymes. Together they digest all of the food types. Bile separates fat into very tiny droplets. They are then more easily attacked by fat-digesting enzymes from the pancreas. Muscular movements in the intestine wall stir the food and move it along slowly. Digestion is complete by the time the food reaches the end of the small intestine.

The small intestine is not only the main digestive organ, it is also the main organ of absorption. Dissolved molecules of digested food pass through the membranes lining the intestine and enter the bloodstream. There are ridges in the intestine lining, which add extra surface area for

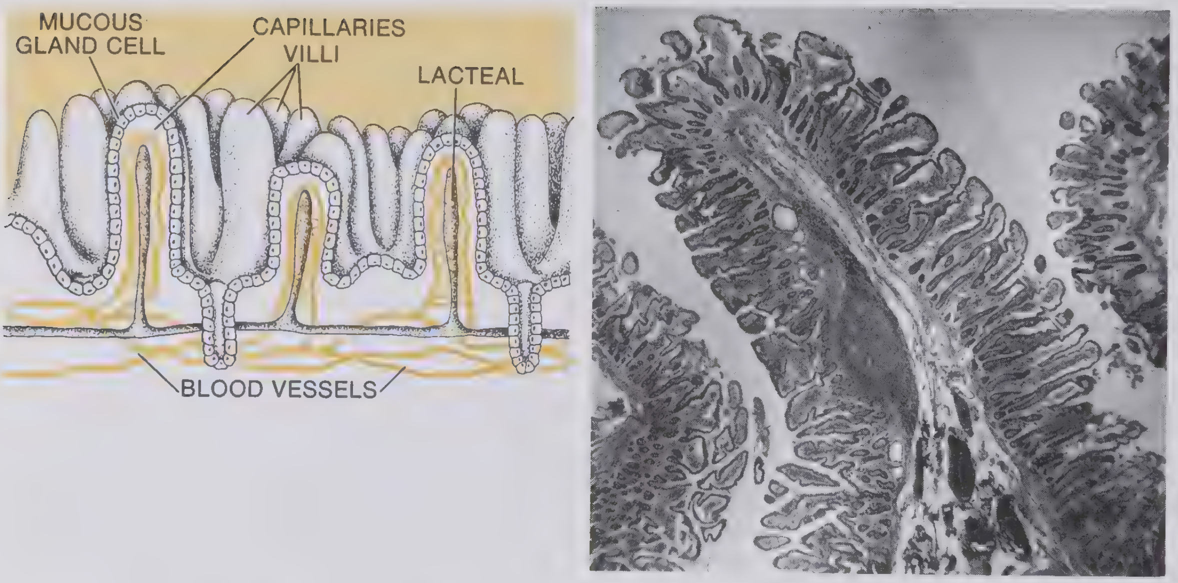


Fig. 39-4. Left: diagram of villi. They contain blood vessels that absorb the digested food. Right: a photograph of villi which line the intestine. Note the tremendous amount of surface they have for absorbing food. (Walter Dawn)

absorbtion. Still more surface is provided by the ***villi*** (vil-eye) [sing. *vil*-lus]. These are tiny, finger-shaped bulges covering the inside surface of the small intestine (Fig. 39-4). Villi absorb dissolved food in somewhat the same way that root hairs in plants absorb water and minerals. Each villus contains tiny blood vessels that take in the food molecules. Blood carries the food away to other parts of the body.

The large intestine. The materials that go into the large intestine are not food. They are the waste materials—fibers and cell wall materials—which cannot be digested. These wastes are mixed with water. The function of the large intestine is to absorb most of this water. The small intestine empties into the large intestine on the lower right side of the abdomen.
The large intestine goes up the right side of the abdomen, across the front, and down the left side. It is about two inches across and five feet long. Wastes are held in it for several hours while water is absorbed back into the bloodstream. This leaves the wastes in a more solid form. They become feces that must pass out of the body through the anus.

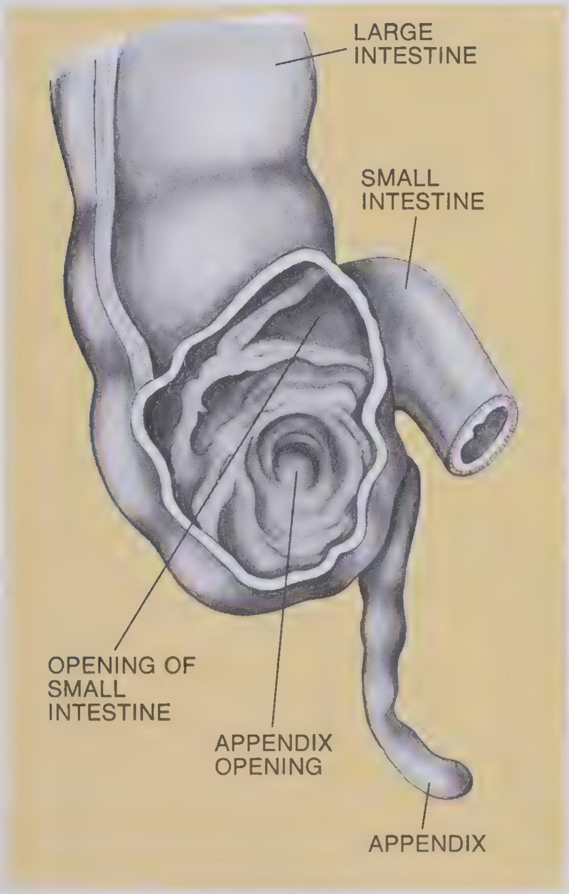
The feces contain more than just undigested materials from food. A great many bacteria are present. The feces also contain waste mineral salts that leave the blood in the wall of the intestine, pass through the intestine lining, and become wastes.

The appendix. The ***appendix*** is a small tube about as thick as your little finger and usually about three and a half inches long. One end is closed. The other opens into the large intestine just below the point where the small intestine enters it. (Fig. 39-5). The ap-

pendix has no function in man. In some other animals, especially the plant eaters, it is a useful organ. It helps the large intestine absorb water. In these animals, the appendix is large, but in man it is small and useless.

Actually there are several such shrunken, useless parts in the human body. We do not have fur as do most mammals, but only a thin covering of tiny hairs. Our tail bones are less than two inches long and do not even show outside the skin. If some part of the body is not needed by a species it is likely to become smaller as time goes on. Mutations take place to cause this reduction.

Fig. 39-5. Connection between the appendix and the large intestine.



When the human appendix is infected by bacteria, the disease is called ***appendicitis*** (ap-pen-duh-*sy*-tis). This is very dangerous, because the infection can cause the wall of the appendix to break down. If this happens the dangerous, pus-forming bacteria spread all through the body cavity, and death can result. Doctors prevent this by removing the infected appendix.

Any pain in the abdomen could be due to appendicitis. It may or may not seem to be in the lower right side. The patient is often sick enough to vomit. If such a pain lasts for three or four hours, it is best to call a doctor. Usually it is not appendicitis, but you should not take a chance. Do not take a laxative at such times. A laxative increases activity in the intestine and possibly causes the breakthrough of the appendix wall to come much sooner.

As a matter of fact, it is better if you do not give yourself medicines at any time. If you are sick enough to need them you are sick enough to see a doctor. With his years of training and experience he has a better chance of understanding your illness than you have. You do not know what is wrong with you when you get sick. Neither do you understand the action of the different drugs. You are very likely to take the wrong medicine if you try to be your own doctor.

ACTIVITY

Digestion and absorption. Take two six-inch lengths of cellophane

dialysis tubing and tie one end of each tube tightly with string. Inside one tube place a mixture of starch and water to which you have added some saliva. In the other tube place a mixture of starch and water. Or, if you wish, you may use chewed-up cracker in one tube and wet cracker crumbs in the other. In either case, test the food material first to be sure that it contains starch, but no sugar (see tests on page 346). Place the closed end of the tubing in a small beaker of water. Let the open end hang over the edge of the beaker. Place the beaker in an incubator if you have one.

An hour or two later divide the water from each beaker into two parts. Test one part for starch and one for sugar. What are your results? What does this show about the digesting powers of the saliva? What does it show about the ability of starch and of sugar to pass through membranes? What were the results in the tube without saliva? Where does digestion take place in your body? What membranes must the digested food pass through?

CHECK YOUR FACTS

1. **What is digestion?**
2. **How does chewing aid in digestion?**
3. **What is the structure of teeth? What kinds of teeth are there?**
4. **What causes tooth decay? How can it be prevented?**
5. **Where is saliva produced? What is its function?**
6. **Where is each of the following organs located, and what is its function: esophagus, stomach, small intestine, large intestine, liver, pancreas?**
7. **Where do the digested food molecules go?**
8. **What does the appendix do? What is appendicitis?**

CHAPTER

40

Circulation

You know a number of things about blood already. You know that it carries materials around the body. You know that it is pumped through tubes called blood vessels. You have found that in simple animals such as *Hydra* or a sponge, each cell is near the oxygen, food, and other things needed for life. These animals get along without blood because every cell can get what it needs from the water. In our bodies most cells have no contact with the outside environment. These cells obtain materials they need from the blood.

The composition of blood. The liquid part of the blood is called ***plasma*** *(plaz-*ma*)*. Drifting in the plasma are a large number of blood cells. The basic material in plasma is water. In it are dissolved a number of salts, including common table salt, calcium salts, and others. Plasma contains food molecules on their way from the digestive system to the body tissues. It carries carbon dioxide and other waste products. Plasma also contains molecules of special proteins. These are known as the ***blood proteins.***

Blood proteins have many functions. They help to hold water in the blood vessels, so that it does not pass out through the vessel walls. Certain blood proteins destroy disease germs. Others unite with food molecules and carry them around the body. One blood protein can turn into a gummy, semi-solid form. This tangles with other things in the blood, forming a ***clot.*** Clots plug up cuts and stop bleeding. Without this self-sealing feature in our blood we would be in danger of bleeding to death from any small wound.

There are two types of blood cells. They are the ***red cells***, and the ***white cells.*** There are also many tiny things called ***platelets*** (Fig. 40-1). The *red cells* are the most numerous blood cells. A drop of blood the size of a pinhead would contain five million of them. They are disc-shaped, and they contain the red iron compound that carries oxygen. Plasma has a clear, yellowish color. Blood looks red because of the red cells in it.

When red cells reach a place where there is plenty of oxygen, their red substance unites chemically with the oxygen. This happens in our lungs. It also happens in the gills of fish. Later, when these same red cells pass through a tissue that contains little oxygen, the red substance releases its oxygen atoms. This oxygen can

Fig. 40-1. Human blood cells and blood platelets.

then be used by the cells in that tissue. Then the red cells are carried back to the lungs by the flowing blood. There they load up once more with oxygen to be carried to the body cells. The blood is the body's transportation system, and the red cells are like little red boxcars that specialize in carrying oxygen.

White cells look very much like *Amebas*. There are several kinds of these white cells. They are clear, colorless, and have no definite shape. They move about under their own power just as an *Ameba* does. There are always some of them in the blood, but many others are found in the body tissues. They can pass between the cells of small blood vessel walls. In this way they enter or leave the bloodstream.

While the white cells roam about the body in this way, they do some very useful work. Some of them destroy

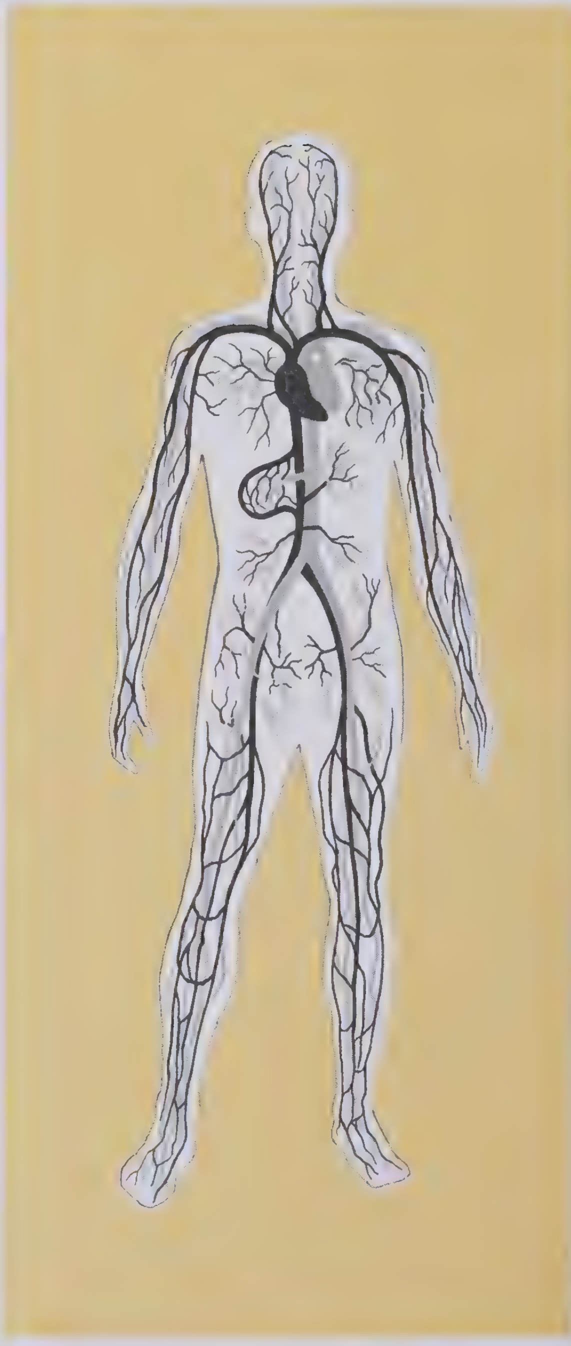


Fig. 40-2. The main blood vessels. Gray represents blood rich in oxygen. Black represents blood that is poor in oxygen. The arteries are shown in gray over most of the body, but black in the lungs. Why is this so?

bacteria or other disease germs. This prevents the bacteria from multiplying and causing disease. Wherever germs enter the body, white cells swarm into the area and attack them. In these battles many white cells are killed by poisons the germs produce. If the bacteria succeed in growing and multiplying, the person becomes sick. The white cells, helped by blood proteins, finally win almost all of the battles, and the person becomes well again. In fact, the white cells never lose a battle more than once.

The *platelets* are known to have at least two functions. They stick to the walls of injured blood vessels, thus helping to hold in the blood. They also start the clotting process. When they contact the rough edges of a wound, the platelets go to pieces and release a certain enzyme. This enzyme reacts with the calcium salts and blood protein in the plasma that we mentioned before. The protein turns semisolid, producing a clot.

Blood cells do not live long. Red cells wear out in about 90-120 days. Certain kinds of white cells last only a day. New blood cells must be made to replace the cells that die. Red cells, platelets, and many of the white cells are produced in the bone marrow. Marrow cells are able to divide. New cells produced in this way become specialized to form the different kinds of blood cells. Some kinds of white cells are produced in another kind of tissue, that will be discussed later in this chapter.

Circulation of blood. Blood is pumped by the *heart*. It moves around the body in closed tubes, the blood vessels. Blood vessels that carry blood away from the heart to the body tissues are called ***arteries*** *(ar*-ter-eez*)*. Vessels that bring blood back to the heart from the body tissues are called ***veins.***

As an artery leads away from the heart, it branches into smaller and smaller arteries. The smallest branches reach into all parts of the body. The job of the arteries, then, is to carry blood into the body tissues.

Many small veins gather blood from the body tissues. These small veins join to form larger ones. These join to make still larger ones, and so on. Finally, the largest veins empty into the heart.

The smallest arteries do not join the smallest veins directly. The body tissues contain a network of very tiny blood vessels called ***capillaries*** *(kap*-i-lehr-eez*)*. They are the smallest of all the blood vessels. Many are so small that red cells must go through them in single file. Every cell in your body is close to some capillary. A single pin prick will break through several of them. The smallest branches of the artery system empty into the

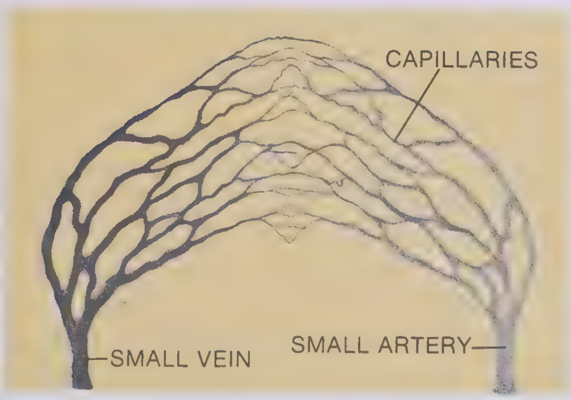


Fig. 40-3. Note how the small arteries break up to form capillaries, and how these come together to form veins. What changes take place in the blood while it is in the capillaries?

capillary networks (Fig. 40-3). Blood from the capillaries flows into the smallest veins.

Capillaries are the vessels that actually supply the body cells with the things they need. The capillary walls are so thin that molecules in the blood can pass out through them. Also, molecules from the body tissues can pass into the capillaries. We said the red cells are boxcars in the transportation system. In the same way, the capillaries are the loading and unloading platforms.

Exchanges between the blood and tissues. While blood is in the capillaries it loads and unloads different materials that it carries. These materials include *food molecules*, *oxygen*, and *carbon dioxide*. There are also dissolved *mineral salts* and the *nitrogen compounds* formed when proteins break down in the body cells. These are wastes which must be gotten rid of. Blood carries other things at times also, but in this chapter we shall only discuss these five kinds of materials.

The following list will give you an idea of the exchanges that take place between the blood and the body tissues in several different sets of capillaries.

1. *Capillaries in muscle, skin, bone, the brain, and several other tissues:* Oxygen and food leave the blood. Carbon dioxide and nitrogen-containing wastes enter the blood.

2. *Capillaries in the lungs:* Food and carbon dioxide leave the blood. Oxygen and nitrogen-containing wastes enter the blood.

3. *Capillaries in the villi of the small intestine:* Oxygen leaves the blood. Food molecules, carbon dioxide, dissolved mineral salts, and nitrogen-containing wastes are picked up.

4. *Capillaries in the kidneys:* Oxygen, food molecules, and nitrogen-containing wastes leave the blood, while carbon dioxide is picked up.

You can see that the function of the heart, arteries, and veins is to move blood from one set of capillaries to another. Each body tissue gets the molecules that it needs from the blood. Each tissue adds wastes to the blood materials.

The pumping of blood. When you were younger you may have used a hollow rubber ball as a squirt gun. You put a small hole in the side of it and filled it with water. When you squeezed the ball, the water shot out. Your heart works in somewhat the same way. It is hollow and filled with blood. Of course you do not have to squeeze it with your hand. The heart is made of muscle, and it does its own squeezing. Each time the muscle tissue in the heart wall squeezes inward, blood is forced out of the heart through the arteries. Each time the muscle tissue relaxes, the heart opens up again and new blood flows in from the veins to fill it.

Actually your heart is two pumps. The right side and left side pump blood separately, and the blood in the two sides does not mix while in the heart. Each side of the heart has two hollow spaces (Fig. 40-4). Each upper space is called an ***auricle*** *(or-ih-kull)*. Each lower space is a ***ventricle*** *(ven-trih-kull)*. Large veins feed blood into the auricles. When the auricles are full, they pump the blood down into the ventricles. Then the ventricles

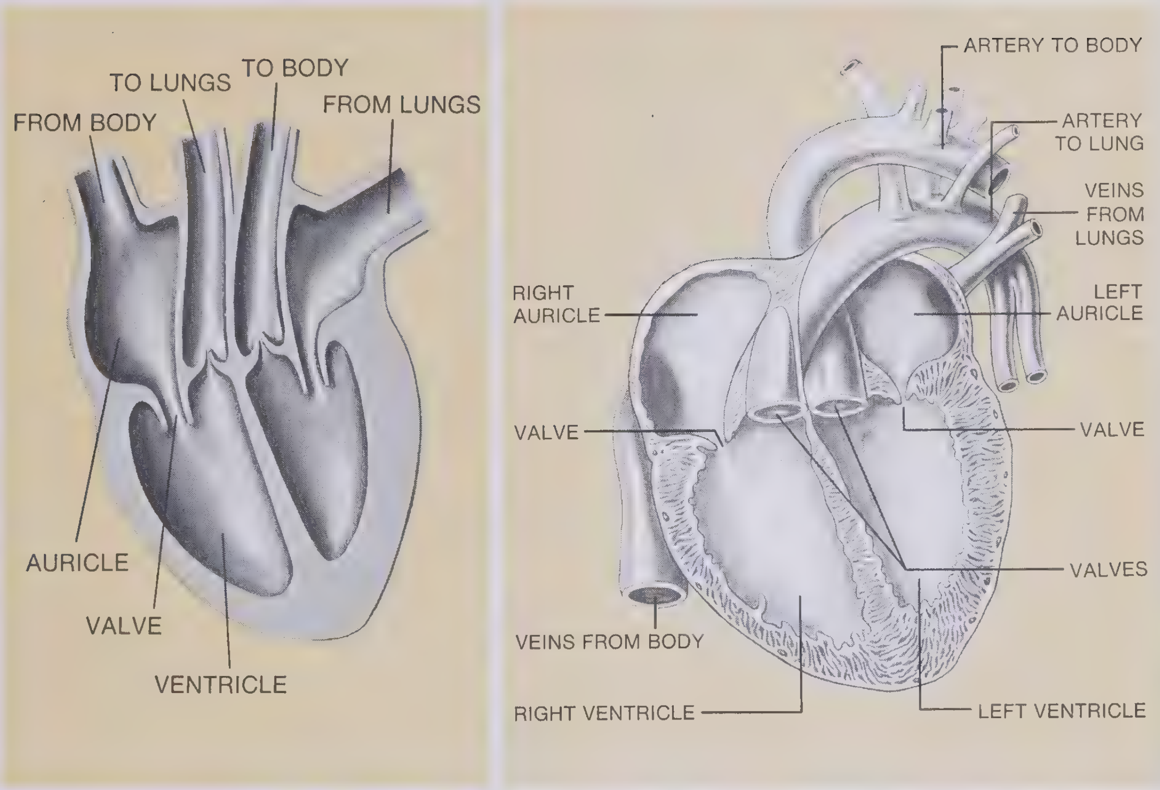


Fig. 40-4. Left: a simple diagram of the heart. Right: a more detailed drawing of the heart. What things have been left out in the first drawing?

force it out into the arteries. Both auricles contract at the same time. Both ventricles also contract at the same time. The pulse that you can feel in an artery is the surge of blood sent out each time the ventricles contract.

Like any other pump, the heart must have ***valves*** to keep the blood from backing up. The edges of the openings between each auricle and ventricle are made up of thin, tough sheets of connective tissue. When blood passes downward into the ventricle, these flaps of tissue are pushed aside. If blood starts upward through the opening, the flaps are pushed inward and meet. They close the opening like swinging doors. There are tough fibers attached to the edges of the valves that keep them from swinging too far.

Other kinds of valves are located in the large arteries where they leave the heart. They are formed of little pockets of thin tissue that are pushed aside when blood goes outward. When blood tries to back up, the pockets fill with blood and plug the artery. Similar valves are located every so often along the veins all through the body (Fig. 40-5).

When any body muscle contracts, it shortens and gets thicker. These thickened muscles squeeze against the veins in that region. This puts pressure on the veins, caving them in and forcing the blood along. The blood can go only one way because of the

valves in the veins. In this way ordinary body movements push blood through the veins toward the heart.

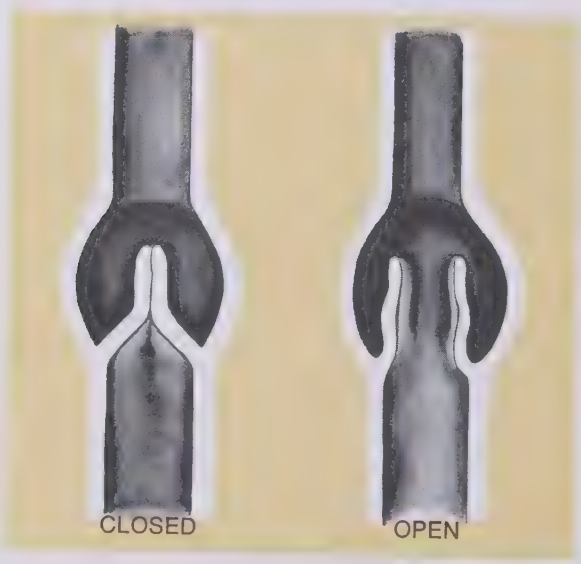
The route the blood takes through the body. Remember that the heart is a double pump. The right and left sides are separate. We can sum up the route blood takes in two pairs of sentences. If you learn them you will know the story of circulation:

1. Blood enters the right side of the heart from all over the body. It is sent from there to the lungs.

2. Blood from the lungs enters the left side of the heart. From there it is pumped all over the body.

Any one drop of blood might go through capillaries in the leg on one trip around the body. The next time it might go to an ear, hand, foot, or eye, depending on which artery branch it happened to enter. But all of the blood goes through the lungs every time around. A drop of blood might go through the left lung one time, and the right one the next time, but it would go through some lung capillary every time.

Fig. 40-5. A valve in a vein. Which way is the blood moving?



Why are the lungs so important? Blood takes on oxygen in the lungs and, of course, oxygen is important. But so is food. Both food and oxygen are necessary to produce energy in the body, yet the whole bloodstream does not pass through the intestines on each round to pick up food. Food can be stored in the cells. Oxygen cannot. Because it cannot be stored, oxygen must be supplied all the time, day and night. You cannot breathe a "meal" of oxygen and then hold your breath for several hours.

There are two large veins entering the right auricle. One brings in blood from the head and arms. The other brings blood from the lower part of the body. Four veins bring blood back from the lungs to the left auricle. Each ventricle connects with a single large artery. The one to the lungs branches just above the heart to go to the two lungs. The one leaving the left ventricle arches over and down behind the heart. It passes down through the body and finally splits to send a branch down each leg. Other branches leave this main artery all along the line, going to the head, arms, stomach, kidneys, and all other parts of the body.

The lymph system. Blood is not the only liquid that moves in the body. There is a clear liquid present in all the tissues of the body. It fills any vacant spaces there may be between the cells. This liquid is called *tissue fluid*. It is what fills blisters in the skin. It is the clear fluid that oozes out over the surface of a skinned knee or elbow.

Tissue fluid is much like plasma, but more watery. It is formed from molecules of water, salts, and other materials that leave the blood. They pass out through the capillary walls into spaces between the body cells. The fluid bathes the cells, keeping them moist and giving them nourishment. It is a go-between for the blood and the body cells.

Some of the tissue fluid returns to the bloodstream by way of little tubes called *lymph vessels.* After the fluid enters these lymph vessels it is called *lymph (limf).* The lymph vessels start out in the body tissues, and carry lymph toward the general region of the heart. At first they are no bigger than capillaries. They contain valves, much as veins do. Exercise moves lymph through these vessels just as it moves blood through veins. The lymph vessels empty into the bloodstream at two places in the large veins just above the heart.

Every so often along the way lymph vessels pass through little glandlike swellings. These are ***lymph nodes.*** They contain large numbers of white blood cells. White cells destroy germs or poisons that have entered the lymph from infected body tissues. The lymph nodes, then, are filters that clean up the lymph before it returns to the blood.

The lymph node tissue has two other functions. It produces some of the body's white cells. Lymph node tissue also produces some blood proteins, especially those that combat certain diseases.

This type of tissue is found not only in the small, scattered lymph nodes, but also in the tonsils, adenoids, spleen, and at many places in the intestine wall. In all of these locations this tissue destroys germs. You have probably noticed how your tonsils and the small lymph nodes in your neck swell up when you have a cold.

Blood filters. Like lymph, the blood also has filters to remove germs and other harmful materials. These are the liver and ***spleen.*** You already know what the liver looks like. The spleen is smaller. It is located in the upper left part of the abdomen, back of the stomach. The liver and spleen destroy germs, worn-out red blood cells, and some poisons that enter the bloodstream.

The spleen also stores extra red cells. If you should go suddenly from low country to the high mountains, you would feel out of breath because the air is less dense at high altitudes. Each breath would bring you less oxygen than you are used to. The spleen acts in this situation by sending many new red cells into the circulation. This adds to the ability of the blood to carry oxygen. After a few days you are much better adjusted to the high altitude.

Health of the circulatory system. As you probably know, heart disease is much more common than it used to be. One of the reasons for this is that more people are living long enough to get heart trouble. In the past many of them would have died much earlier of germ diseases such as smallpox, diptheria, and pneumonia.

If we do not die of germ diseases, we live until some vital part of the body wears out. The heart and arteries are often the first organs to break

down. Some general rules of good health will help to make your heart and arteries last longer. Of course, good food is needed for any system of the body. We need iron, proteins, and several vitamins to build red blood cells. It is believed that too much fat in the diet causes artery damage. Being overweight is also hard on the heart and arteries. We should stay at normal weight all through life. Smoking seems to damage the heart. Heart attacks may result when a weakened heart is overworked.

Exercise is good for health but it should not be too strenuous or come too suddenly. A burst of exercise may cause heart damage, especially in middle-aged people.

Nervous tension leads to several kinds of diseases. Heart trouble is one of them. A relaxed outlook on life is important in today's world.

ACTIVITY

Wrap a goldfish in a thin layer of wet cotton. Let the tail fin stick out. Lay the fish in an open Petri dish and spread the tail fin out flat. The wetness will probably hold it in place. If not, a strip of wet paper placed flat across the outer end will probably hold it. Examine the exposed part of the tail fin through the low power of the microscope. You will be able to see blood flowing in the thin membrane of the fin. Can you recognize the veins? Arteries? Capillaries? How can you tell them apart? If you do not take too long with this experiment the fish will still be alive and healthy when you return it to its aquarium.

CHECK YOUR FACTS

1. What does our blood do for us?
2. What do we call the liquid part of the blood? What does it contain?
3. What are the two kinds of blood cells? What does each of them do?
4. What causes blood to clot?
5. How long do blood cells last? Where are new ones produced?
6. Describe the three kinds of blood vessels. What happens in each kind?
7. How does the heart pump blood?
8. Trace the route blood follows in moving through the body.
9. What is lymph? What is its function? How does it circulate?
10. What are lymph nodes? What is their function?
11. What do the liver and spleen do for the blood?
12. Give some good rules for helping the circulatory system to stay healthy.

CHAPTER 41

Respiration

You have studied respiration in the cell. It sets free energy to do the cell's work. The simple sugar, glucose, is broken down, releasing energy. Oxygen unites with the products of glucose breakdown, forming carbon dioxide and water. In the last chapter you learned how the blood carries oxygen to the cells of tissues. Also, how the blood removes carbon dioxide from these cells.

Now we shall study the way in which the blood gets its oxygen supply and how it gets rid of carbon dioxide. This is the job of the human respiratory system. Its parts are the *nasal passages*, *voice box*, *windpipe*, *lungs*, *ribs*, and *breathing muscles*.

The parts of the respiratory system. The *nasal passages* are spaces above the roof of the mouth. Air passes through them from the nose to the throat. From there the air goes down past the back of the mouth and into the voice box (Fig. 41-1).

The nasal passages are convenient by-passes around the mouth. They make it possible to breathe and chew at the same time. They also produce changes in the air that passes through them. The tissue lining the nasal passages is always covered with a film of moisture. Air is warmed and moistened as it passes through. Cold dry air could harm the delicate linings of the lungs.

Many of the dust particles in the air stick to the moist lining of the nasal passages. This filtering action also protects the lungs. The nasal passage lining is covered with cilia, like those *Paramecium* uses to swim with. These beating cilia cause the moisture film to move backward through the nasal passages in the direction of the throat, and the dust is carried with the film. The lining of the windpipe also catches dust and moves it up to the throat. The dust particles in the throat are usually swallowed. Then they pass harmlessly through the digestive system. They would do damage if they accumulated in the lungs.

The ***voice box*** really *is* like a box. It is hollow and its walls are stiffened by sheets of cartilage. It has a lid that is pushed down to close the opening when we swallow. This keeps food from going down the wrong way. Study Fig. 41-1 and see why we need this valve action. The esophagus lies just behind the windpipe. Food entering the esophagus slides over the opening to the voice box. If this opening did not close when you swal-

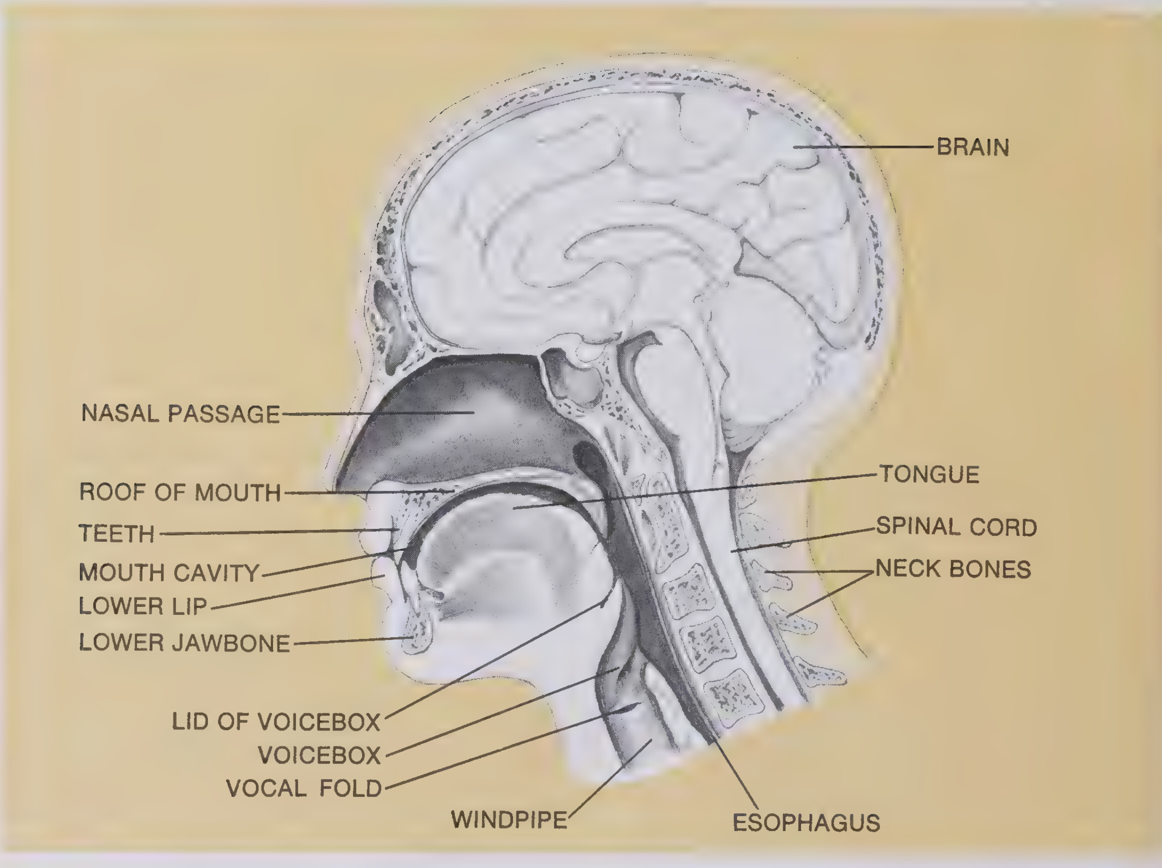


Fig. 41-1. The air passages of the head and neck.

low, you would inhale your food instead of swallowing it.

Sometimes a little food does slip into the voice box. This is very irritating to nerve endings in that area. The person begins to cough, and this drives the food out. This choking reaction is unpleasant, but it prevents liquids or solids from entering the lungs.

A second function of the voice box is to produce sound. There is a flap of strong tissue on each side of the voice box. These are the ***vocal cords.*** They can be moved against each other to close the passage, or they can be pulled back to leave a large opening. When their edges are stretched and air is forced between them, they vibrate. This produces sound. In singing a high note, the vocal cords are stretched tightly. For low tones they are stretched less tightly. Men's voices are lower than women's because their voice boxes, called "Adam's apples," are bigger. Their longer, heavier vocal cords vibrate more slowly, producing lower tones.

The vocal cords have another function besides producing sound. When we strangle on food they clamp shut to prevent any solids or liquids from entering the air passage. They aid also in coughing. When we cough, the vocal cords close the air passage and then open it suddenly, allowing air to

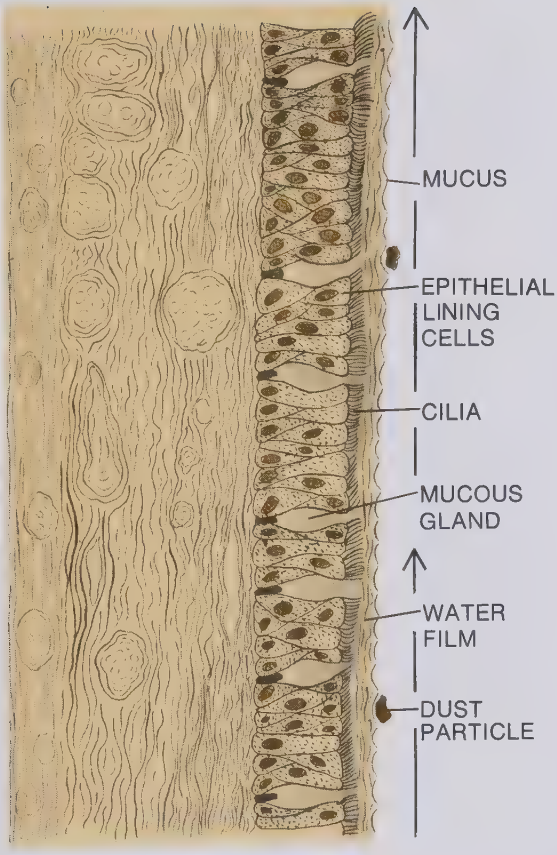


Fig. 41-2. Cells lining the air passage. Note how they are covered with cilia and a film of moisture. When dust sticks to this film what becomes of it?

rush out. Coughing serves to clear the air passages of the neck and chest.

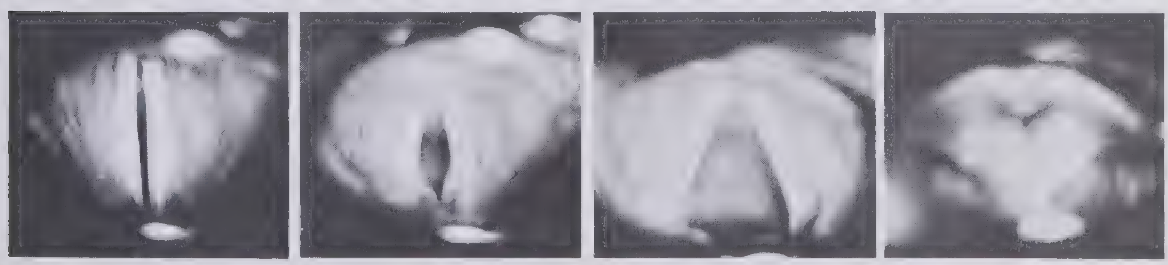
The ***windpipe*** is a tube that leads from the voice box down into the chest. It has rings of cartilage in its walls that hold it open at all times. At its lower end the windpipe divides, sending one branch to each lung (Fig. 41-4). One lung fills each side of the chest cavity, with the heart in the middle. In the lungs, the air passages divide again and again until all parts of the lung tissue are reached by the branching air tubes.

Each of the final small branches of this tube system opens into a cluster of tiny ***air sacs.*** These tiny air sacs have very thin walls. Their walls are surrounded by networks of capillaries (Fig. 41-5). These capillaries enter the walls of the air sacs. Each lung is a great mass of these air sac clusters.

The exchange of gases. Oxygen molecules from the air in the lungs pass through the walls of the air sacs and into the capillaries (Fig. 41-6). Red blood cells absorb this oxygen and carry it to the body tissues. At the same time, carbon dioxide from the blood passes into the air that is within the air sacs.

The air we breathe in contains about 20 percent oxygen and just a slight trace of carbon dioxide. The air we breathe out has 16 percent oxygen and four percent carbon dioxide. In

Fig. 41-3. These are actual photographs of the vocal cords in action. From left to right: falsetto, loud low tone, a whisper, a cough. (Bell Telephone Laboratories)



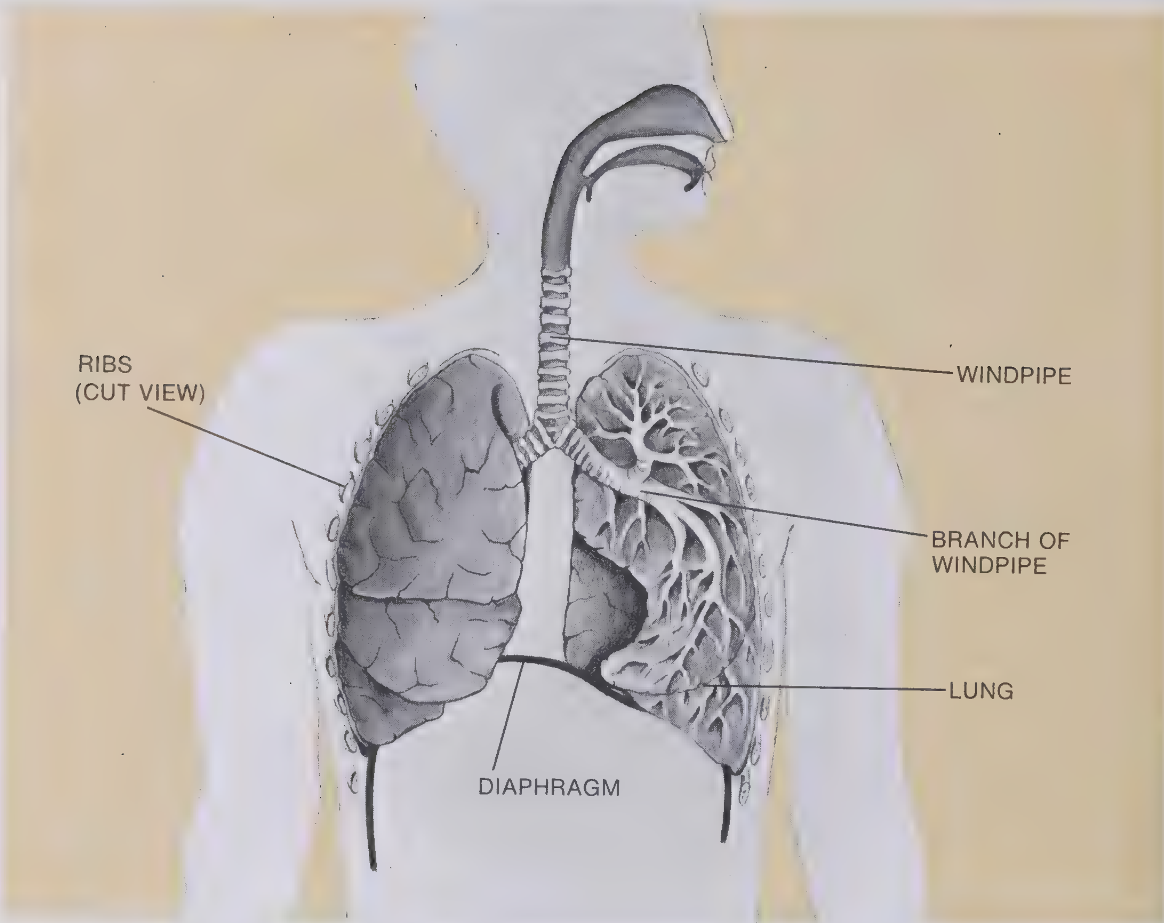


Fig. 41-4. Note how the ribs, muscles, and diaphragm completely enclose the lungs in a sort of box. What happens when the diaphragm pulls downward?

other words, we trade carbon dioxide for oxygen in about equal amounts.

The breathing process. ***Breathing*** is the act of moving air in and out of the lungs. The floor of the chest cavity is the dome-shaped *diaphragm*. When muscle fibers in the diaphragm contract, it is pulled downward. The stomach, liver, and other digestive

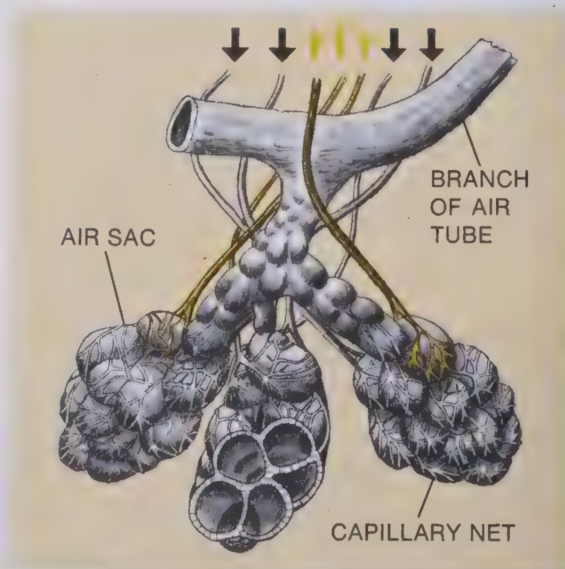


Fig. 41-5. A cluster of air sacs at the end of a tiny air tube in the lung. Note the network of capillaries around each sac.

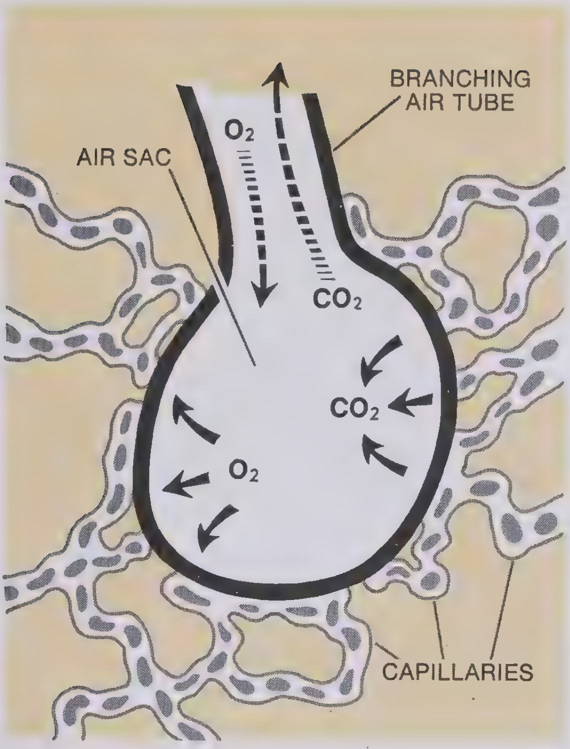


Fig. 41-6. The exchange of oxygen and carbon dioxide between air and blood in the air sac. Where does each of these gases come from? Where does each of them go?

organs are pushed down ahead of it, bulging the front wall of the abdomen outward. Muscles in the abdominal wall must relax to allow this to happen. At the same time that the diaphragm moves downward, the rib muscles contract and lift the ribs outward and upward. Both the action of the diaphragm and that of the ribs increases the size of the chest cavity so that air rushes into the lungs.

When the rib and diaphragm muscles relax, all of these parts spring back into place, pushing air back out of the lungs. In ordinary quiet breathing this is enough. When we wish to talk, sing, or breathe deeply we must actually force air out of the lungs. This is done mainly by contracting the muscles of the abdominal wall. This action moves the digestive organs back up against the diaphragm, forcing it upward against the lungs and pushing air out of the windpipe.

The diaphragm action is more important than the rib movement in breathing. Without the ribs, however, the diaphragm could not do its work. The ribs stiffen the chest wall. Without this stiffening, the chest would simply cave in when the diaphragm moved downward.

Health of the respiratory system. The lung and air passage linings are moist and delicate. Disease germs often attack them. Many germ diseases have been brought fairly well under control, but several of those attacking the respiratory system still give us trouble. Colds, influenza, and pneumonia are some of them. Colds and influenza are caused by viruses. So is one kind of pneumonia. But most pneumonia attacks are due to the presence of certain bacteria in the lung tissues.

The viruses and bacteria that cause such diseases are found everywhere. Whether or not we become sick from these diseases depends upon our body resistance to them. Several things help to keep up this disease resistance. One, of course, is good food. Vitamins A and C have direct effects upon the health of the membranes lining the air passages. Getting plenty of rest is important. People who are tired out are more likely to get sick. Being chilled also lowers resistance to respiratory illness, so that wearing warm clothing in cold weather is important.

Certain kinds of dust can damage the lungs. Very fine sand particles may be thrown into the air by drilling and blasting in hard rock. Breathing asbestos fibers can harm the lungs. Many paint sprays are poisonous, and most sprays used on fruit trees are dangerous to breathe. Men who work in mines, foundries, factories, or orchards where these dangerous materials are present must be protected. One method is to use filter masks. These take out the dusts before they can enter the nose. Masks are hot and uncomfortable, so a better way is good ventilation. You cannot "ventilate" an orchard, but you can ventilate a mine or a factory.

When you spray orchards, a filter mask should always be used.

ACTIVITY

Testing your breath. In the activities for Chapter 3 you learned that limewater can be used to test for carbon dioxide. In the Chapter 4 activity you learned that food material, such as a peanut can burn to release energy. You know that foods release energy in your body. Does your body release carbon dioxide during this process? To find out, place some limewater in a test tube. Put a soda straw into the limewater and blow bubbles into it. Does the limewater turn milky? Explain what this shows about respiration in your body.

CHECK YOUR FACTS

1. What is respiration? What does the respiratory system do?
2. Where are the nasal passages? What three changes take place in the air as it passes through the nasal passages?
3. What are two functions of the voice box?
4. Describe the structure of the lungs.
5. What gases are exchanged in the lungs?
6. What draws air into the lungs? What forces air out of the lungs?
7. How can we maintain the health of the respiratory system?

CHAPTER

42

Excretion

Excretion is the process of getting rid of wastes. The human body produces several kinds of wastes and gets rid of them in different ways. You already know about some of these. The waste produced in greatest quantity by the body cells is carbon dioxide. You know how it is carried by the blood and given off through the lungs. Bile has a digestive function, but it also contains waste materials which leave the body in the feces. The feces also contain waste mineral salts coming through the intestine lining from the blood. Undigested materials from foods which have been eaten have never really entered the body tissues. For this reason the passing of these materials from the large intestine is not considered true excretion.

Waste in the form of mineral salts and nitrogen compounds. Chapter 40 mentioned another class of wastes that are produced in the body cells. As protoplasm is built up and broken down, mineral salts are produced as wastes. Also, the products of protein breakdown always include nitrogen compounds, which are usually called ***nitrogenous*** (ny-*troj*-en-us) ***wastes.*** Some of these compounds come from ordinary body cells such as those in the muscles. Most of them come from protein foods which are not used in building protoplasm. These are broken down in the liver to form energy foods like fats and glucose. Now the nitrogen in the protein molecules is no longer needed. It is combined with other elements to form a compound called ***urea*** (yoo-*ree*-ah). Urea is the main nitrogenous waste of the human body.

Mineral salts and nitrogen compounds are not gases, so they cannot leave through the lungs. They must pass off from the body dissolved in water. This is done through the *kidneys* and to some extent the *sweat glands*.

Excretion through the kidneys. The two ***kidneys*** are reddish, bean-shaped organs about $4\frac{1}{2}$ inches long. They lie just inside the back body wall under the last two pairs of ribs. A large artery and a large vein connect with each kidney. A duct connects each kidney with the *bladder* at the bottom of the body cavity (Fig. 42-1).

The kidneys filter out a number of waste materials from the blood, especially mineral salts, urea, and other nitrogenous wastes. Even water is a waste when a person drinks more than he needs. The kidneys excrete extra amounts of water at such times. Of

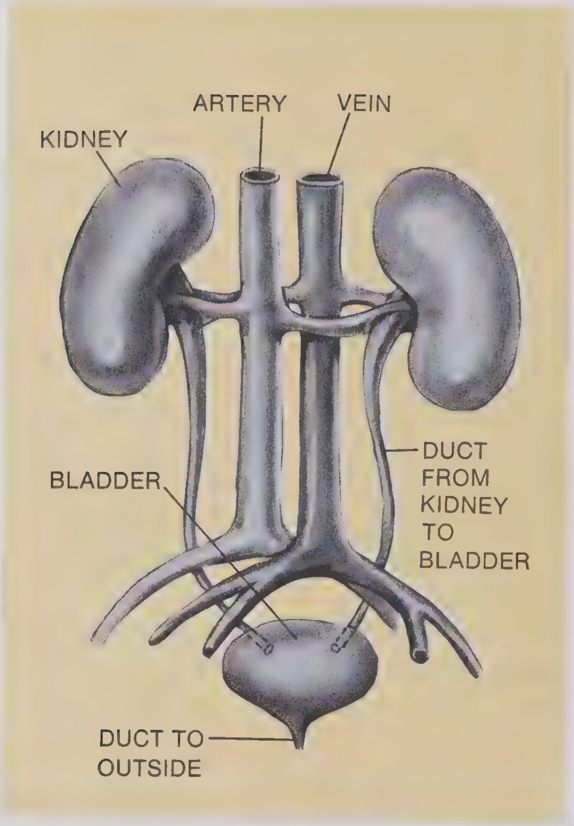


Fig. 42-1. The kidneys and connected structures. Why are such small organs supplied by such large blood vessels?

course some water must always pass through the kidneys to carry off the other wastes. This mixture of water and dissolved wastes is called ***urine*** (*your*-in).

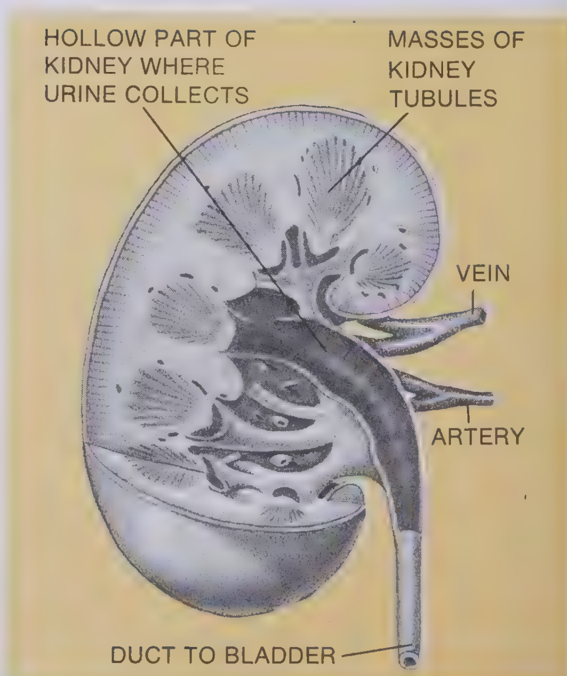
Each kidney is made up of a closely-packed mass of little kidney tubes. If the tubes in one kidney were stretched out, their total length would make about 40 miles of tubing. The capillaries in the kidney are in close contact with these tiny tubes. As blood circulates through the capillaries, the thin walls of the tubes take wastes from it, producing urine. The urine flows down the urine ducts to the bladder.

The ***bladder*** is simply a storage organ. It is a muscular sac which holds the urine until it can be passed off to the outside of the body.

The skin has many functions. ***Skin*** is studied in this chapter because it excretes some dissolved wastes in sweat, but this is not its most important function. The kidneys are the main excretory organs for dissolved wastes. The skin does several other things that are just as important. In fact, the skin is a vital organ. You could not live without it. Skin has the following functions:

1. *Protection.* The skin is a tough covering that protects the inner parts of the body from bumps, scratches, scrapes, and cuts. It keeps out disease germs. The skin holds in moisture,

Fig. 42-2. View of a dissected kidney. Urine is collected by the tiny tubes in the solid, meaty part. It drains into the hollow part of the kidney and flows out through the duct.



guarding the body from the loss of water by evaporation. It protects the body from strong sunlight.

2. *Sensation.* Skin is rich in nerve endings, making it a very important sense organ. Through it we receive sensations of touch, heat, cold, pressure, and pain.

3. *Temperature regulation.* Our bodies often need to lose heat. This heat is lost through the skin. The ways in which skin regulates body temperature will be explained later in this chapter.

4 *Excretion.* As explained before, sweat contains some urea and mineral salts.

5. *Production of vitamin D.* The skin produces vitamin D in the presence of sunlight (Chapter 38).

Structure of the skin. Skin is thicker than you probably realize. When you "skin" yourself you have usually scraped off only the top layer. Over much of the body the skin is nearly one-eighth inch thick. It is tough, like rawhide. In fact it *is* rawhide! The reason we do not think that our skin is tough is because it is so sensitive. Damage to the skin hurts, so we try to protect it.

The skin has two layers, the *outer layer* and the *main layer* (Fig. 42-3). The main layer is thicker and the more important of the two. Under these is a third layer, which is not really skin. It is a layer of fat. The outer layer is something like tree bark—its outer cells are dead and keep rubbing off. Its inner cells are always dividing to replace the dead ones.

The dead cells of the skin surface are filled with a tough protein which makes them strong and scale-like. They protect the living cells underneath. If some spot on the skin is rubbed too much, the living cells below speed up their rate of growth. This produces an extra thick layer of dead cells at that spot. This is how a *callus* forms.

The living cells of the outer skin layer contain pigments, or coloring materials. These pigments absorb the burning rays of the sun and protect the deeper cells from sunburn. Sunburn can be dangerous. Too much of it can lead to skin cancer. Developing a tan, which is really developing more pigment, gives extra protection when it is needed. Races of people whose ancestors lived a very long time in tropical climates usually have dark skins. This is an adaptation to strong sunlight, and it has come about through natural selection. A pale skin is a handicap in such climates.

The main layer of the skin is made mostly of strong connective tissue. In this tissue are located blood vessels, nerves, hair-producing cells, oil glands, sweat glands, and muscle fibers.

Hair is produced by the skin. Hair grows from little tubes which pass down through both layers of the skin (Fig. 42-3). At the bottom end of each tube are cells that divide rapidly, forming the shaft of the hair. As a hair is pushed outward, its cells die. They contain the same tough protein that is present in the dead cells of the outer skin.

A hair keeps growing until it reaches a certain length. Then it falls out, and a new one starts growing in its place. How long the hair gets depends upon where it is. The body hairs, eyelashes, eyebrows, and head hairs each

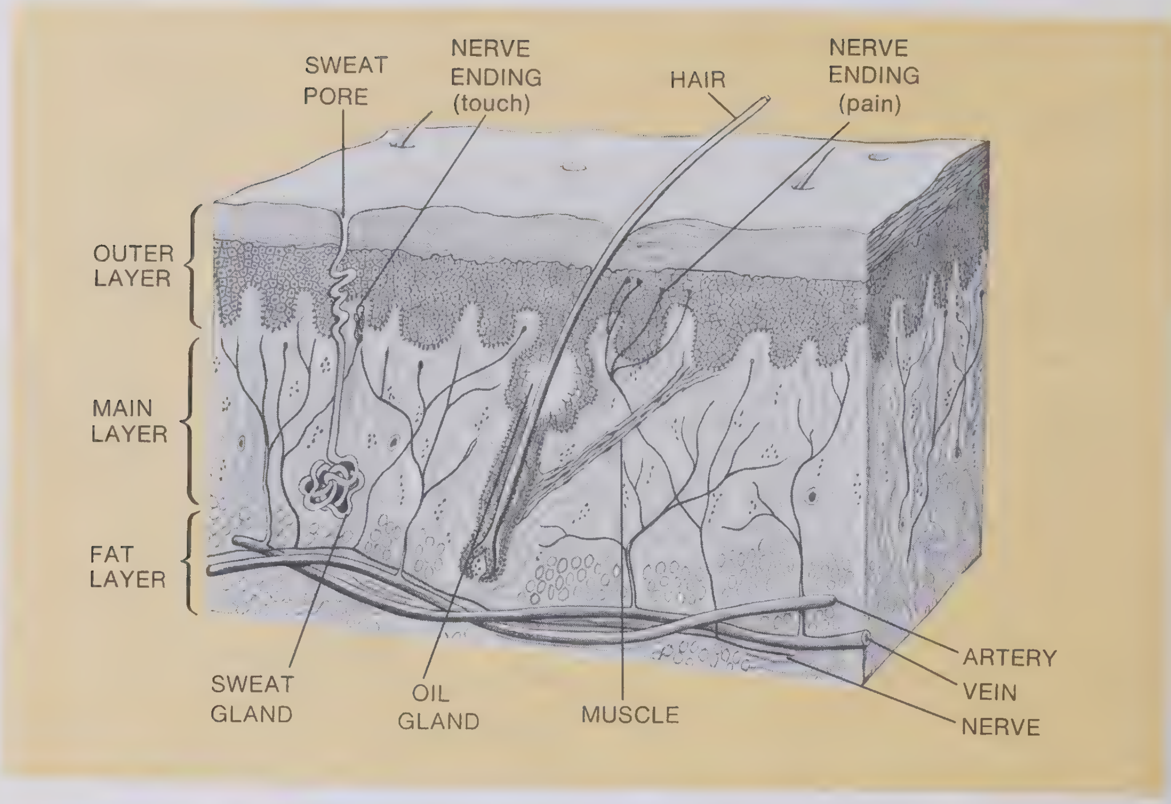


Fig. 42-3. The structure of the skin. Which of these layers of an animal skin is used in making leather?

have definite lengths to which they can grow.

Sometimes a hair falls out, and no new one grows. When this happens to many hairs on the head, the person becomes bald. Baldness can be caused by certain skin diseases. A doctor who is a skin specialist can help in these cases. But most baldness is due to heredity and cannot be avoided (Chapter 10).

The oil glands in the skin produce an oil which flows out through the same tubes that the hair grows through. This oil keeps the hair and skin surface soft. Washing in hot water and strong soap often takes out too much of this oil. The result is dry hair and cracked skin.

Muscle fibers connect with the side of each tube that produces a hair (Fig. 42-3). When these fibers contract, the hair stands on end. You can see this happen on your arm when you have "goose pimples." Your head hair is too long to stand on end. This reaction has no value in man, but in mammals with fur it helps to keep them warm. With the fur standing up, the layer of air trapped between the hairs becomes deeper. This air is a good insulator. It is like putting on an extra coat. Man's body hair cannot possibly keep him warm, but it still stands on end when he is chilly. This reaction seems to be just one more of those leftovers from the past, like the appendix.

The nerves and sweat glands. There are several different kinds of nerve endings in the main layer of the skin. These are what make it so sensitive. The nerve endings of touch are located just under the outer skin layer (Fig. 42-3). The number of these nerve endings varies. Some parts of the body have over 2,000 per square inch of skin. Other parts of the body have fewer nerve endings of touch and are much less sensitive.

The sweat glands have tiny ducts that pass down through the skin. At their inner ends the glands are coiled into tight little balls. Capillaries wrap around these balls of tubing. The cells of the sweat glands extract saltwater from the blood, together with traces of urea and other wastes. This sweat flows out onto the skin, where it evaporates. There is always some sweat forming, but most of the time we do not notice it. It dries up as quickly as it is produced. During hot weather or heavy exercise, the skin may be quite wet.

Regulation of temperature. The skin contains many more small arteries and veins than are needed just to feed its cells. This large blood supply helps to regulate body temperature. Remember that we are warm-blooded animals. The human body temperature is nearly 100° F inside. In the mouth it measures about 98.6° F. If it drops or rises very many degrees, we are in serious trouble.

If too much heat is present in the body, the blood is warmed up. When this blood flows through the skin it loses heat to the air. The skin acts as a sort of radiator that gives off heat. The cooled blood then returns to the inside of the body and is heated again. So extra heat is another thing that the blood carries.

The amount of heat lost by the skin is controlled by muscle fibers in the walls of the skin's blood vessels. When the body is warm these muscle fibers relax, and the blood pressure stretches the blood vessel walls. Their diameter is increased, and extra blood flows into the skin. In this way heat is lost to the air, and the body gets cooler.

When the body is chilled, blood vessels in the skin contract. Now less blood can enter the skin. Most of the blood remains in deeper tissues where it cannot lose much heat. The fat layer under the skin is good insulation, and serves to hold in heat at these times. This fat layer is better developed in women than in men, so women are usually able to stand cold better than men. The more northern races of man have more evenly developed fat layers. This is part of their adaptation to the cold.

On a very hot day the air may be as warm as the blood is. Then the presence of blood in the skin does not cool our bodies. At such times our lives depend on our ability to sweat. Large amounts of sweat flow out on the skin. The evaporation of this sweat is what cools us.

Gas molecules contain more energy than liquid molecules do. When a liquid turns to a gas, it must take on extra heat energy. Water is forming vapor, or turning into gas when it evaporates. This is why sweating cools the body surface. As it turns to vapor, the water removes heat from the skin. Each water molecule carries off some of the heat. In this way people's bodies stay at normal temperature even

when the air around them is warmer than they are.

ACTIVITY

Examining a kidney. Get a pig kidney from the butcher. Slice it open. Notice how the solid red part seems to have a "grain" in it. This is because it is made of thousands of tiny tubes packed side by side. The outer part looks different because there the tubes are all twisted instead of forming straight lines. Notice the hollow part at one side. This is where the urine collects. Find the duct that leads out of this cavity. Where did it lead to when it was in the pig?

Cooling effect of evaporation. Tie a wet cloth around the bulb of a thermometer. Place the thermometer with its lower end in a test tube and its upper end sticking out through a one-hole stopper. Have the cloth wet. Also have a little water in the test tube, but not touching the thermometer. Let the tube and thermometer sit in the room an hour or so. Take a thermometer reading. Does it show a temperature that is higher, lower, or the same as the temperature of the room?

Pull the thermometer and stopper out of the test tube. Allow air to circulate around the wet, cloth-covered bulb. What temperature does it show? Is it being wet that makes things cool, or is it evaporation that has a cooling effect? How does sweating cool us? Why is it more difficult to stay cool on a damp day than on a dry day in hot weather?

CHECK YOUR FACTS

1. **List the wastes that are produced by the body.**
2. **What does the liver do in connection with excretion?**
3. **What do the kidneys do? What are they made of?**
4. **What does the bladder do?**
5. **Name several functions of the skin.**
6. **What does the outer layer of the skin do?**
7. **How does the skin produce hair?**
8. **What do the oil glands do?**
9. **Why do we call the skin an important sense organ?**
10. **How does the skin regulate body temperature?**

CHAPTER

43

Bones and Muscles

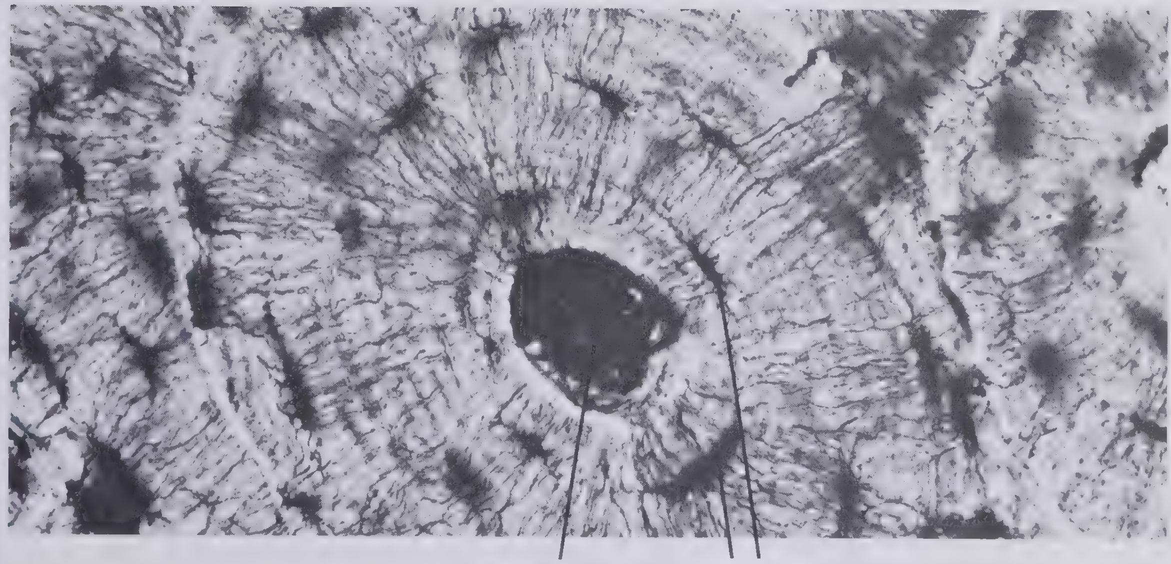
The skeleton is a very useful part of your body. Without it you would have to crawl on the ground like a worm. And the skeleton does more than hold you up. The bones act as levers to make muscle movement more useful.

Another function of the skeleton is to protect certain delicate parts of the body. The skull forms a bony box around the brain. The heart and lungs are protected by the ribs, breastbone, and backbone. The spinal cord, which is a large nerve, is protected by the backbone.

Materials in the skeleton. The skeleton is made of two kinds of material—***bone*** and ***cartilage.*** These are both special kinds of connective tissue. This kind of connective tissue has large amounts of nonliving material between the cells. In bone, a great deal of hard mineral matter is deposited between the cells (Fig. 43-1). Cartilage has a smooth, tough, flexible substance between its cells.

The skeletons of sharks are all cartilage. We have it in the walls of our voice box and windpipe, in the ears,

Fig. 43-1. A photograph of bone tissue taken through a microscope. Note that it contains living cells. What makes it so hard? (Courtesy General Biological Supply House, Inc. Chicago, Illinois)



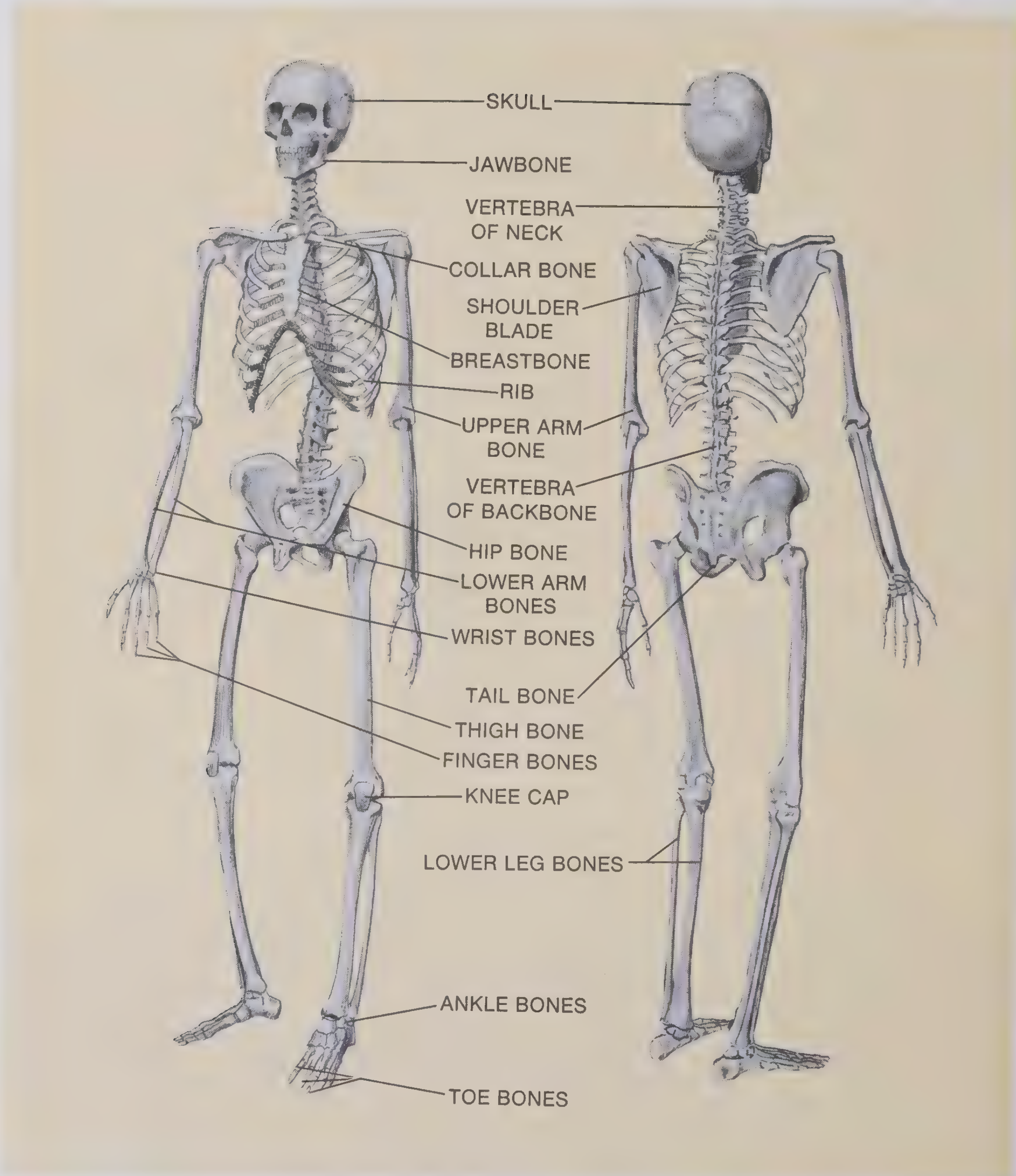


Fig. 43-2. The human skeleton.

the lower part of the nose, and in several other places. Cartilage is tough and strong. It stiffens the structures that it supports. At the same time, cartilage is quite flexible and can bend. Cartilage forms a smooth white covering over the ends of the long bones. You have probably seen this

in joints of meat. Discs of cartilage fill in between the sections of the backbone. Strips of cartilage connect the ribs to the breastbone. This makes the chest wall flexible enough for the breathing movements to take place.

Structure of the skeleton. Bone, of course, is stronger than cartilage. The mineral in it is a collection of calcium and phosphorus compounds. These are bound together by proteins which keep the bone from being too brittle. Bone has many passageways running through it. These contain blood vessels and nerves. There are also tiny passages between the cells. These allow tissue fluid to carry food and oxygen to the living bone cells.

Each bone is covered by a tough sheath that is rich in blood vessels. If a bone is broken, cells from this sheath move into the break and repair it. Healing of broken bones is a slow process. Doctors usually place the broken part in a cast, so the ends of the bone will not move during healing.

There are over 200 bones in the skeleton (Fig. 43-2). They are joined together in several ways. Bones in the hips, skull, and breastbone grow together solidly. Many of these bones are separate in a very young child. However, in skeletons of older people it is difficult to see where some of their joints were. Other joints allow a little movement. The joints between the ribs and the backbone are like this. Some joints allow a great deal of movement. The shoulder, elbow, hip, and knee joints are examples.

A movable joint is really quite complicated. The ends of the two bones are covered with smooth cartilage. This reduces friction. There is also a sheath surrounding the joint. It contains a liquid for lubrication. The two bones are bound together by fibers of strong, tough connective tissue. These are the ***ligaments.*** If we damage our ligaments we say that we have a sprain.

Look again at Figure 43-2. See how everything is centered around the backbone. This backbone is actually a whole row of bones called ***vertebrae*** *(ver*-teh-bree*)* [sing. *vertebra (ver*-teh-bra*)*]. Each vertebra has a disc-like central part that carries the weight. A bony arch is attached to the back of the central part (Fig. 43-3). The whole row of these arches forms

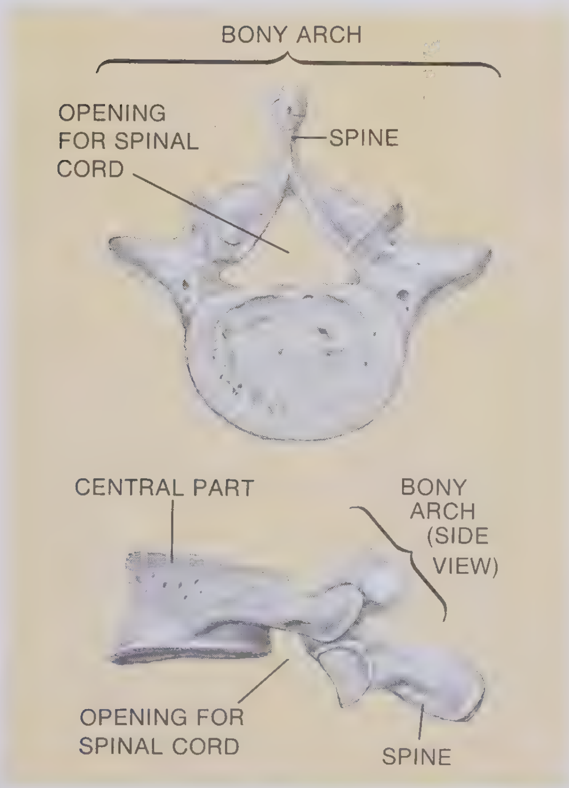


Fig. 43-3. Two views of one vertebra from the backbone. How are these vertebrae connected together?

Fig. 43-4. Note that the same basic pattern is present in all of these vertebrate skeletons. How do you explain this?

a long, protected cavity in which the spinal cord lies. The vertebrae have spines sticking out from them to which the back muscles are attached.

The skull includes many bones that are more or less grown together. The lower jawbone is the only movable part of the skull. Some of the skull bones form the brain case. The rest make up the bones of the face region. There is a movable joint between the base of the skull and the first vertebra.

The hipbones and shoulder bones form bases for the legs and arms. These leg and arm bones are marvelous tools for walking and for handling things. Notice how the two bones of the lower arm can rotate around each other. This makes it possible to turn the hand. The human arm can move more freely in all directions than the leg or arm of any other animal. The ability of a human hand to do fine finger movements is also unusual.

The skeletons of all land vertebrates

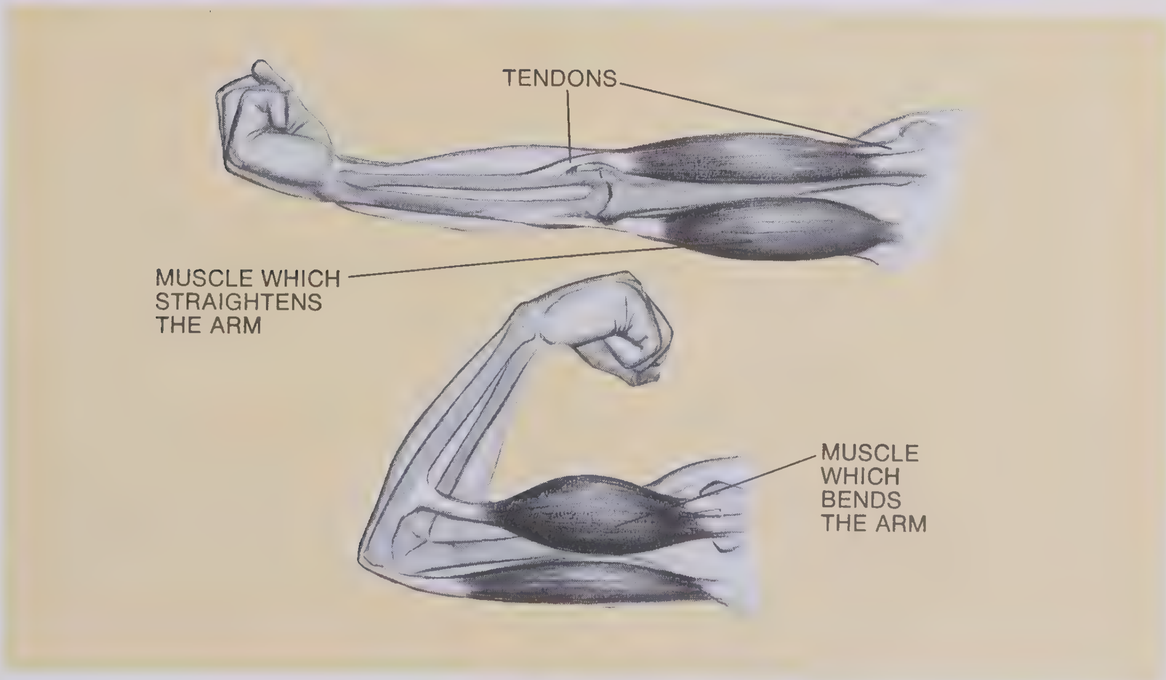
are similar. The mammals, especially, have skeletons very much like ours. The same bones are present, but they have different shapes and sizes (Fig. 43-4). These differences adapt them to different ways of life.

How the muscles work. Think what a good puppet you could make out of a skeleton. You could tie strings in the right places and make it walk, wave its arms, or wiggle its jaw. This is about what does happen when you move around. "Strings" pull your bones back and forth. These strings are tough cords of connective tissue, called ***tendons.*** One end of a tendon is fastened to a bone. The other end connects with a muscle. When the muscle contracts, it pulls on the tendon. This moves the bone. In your muscle and bone system you are like a puppet with built-in motors that pull the strings.

Figure 43-5 shows how the elbow is bent or straightened. One muscle on the front of the upper arm is fastened at its upper end to the shoulder. At the lower end is a tendon that extends across the inside of the elbow joint and fastens to one of the bones of the lower arm. When this muscle contracts it becomes shorter. This pulls the arm into a bent position. Another muscle on the back of the upper arm pulls the arm out straight again. Of course, both muscles do not pull at once. Their movements are controlled by the nervous system.

Note that a muscle only pulls. It cannot push. There are over 700 muscles attached to the skeleton. They can

Fig. 43-5. Each muscle pulls in only one direction. One contracts while the other relaxes. Pairs of muscles like this must be under perfect control so they will cooperate to give smooth movement.



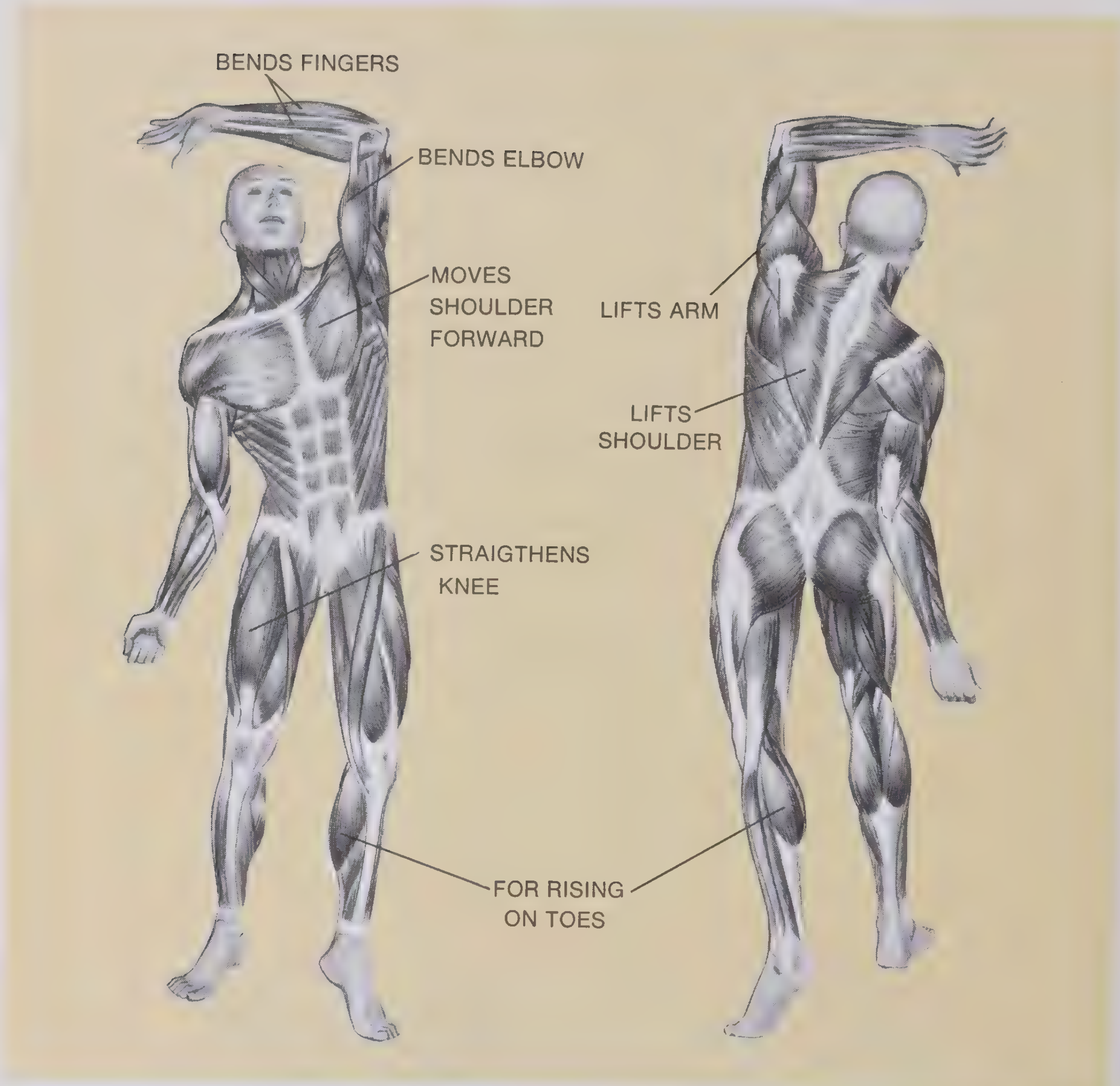


Fig. 43-6. Human muscles. Some are labeled. Can you determine what the others do. Remember that a muscle can only pull.

pull the bones in many directions. Figure 43-6 will show you how they are arranged. Some have long tendons, some short ones. Some attach broadly to the bone, and there is no real tendon present. The hands are especially complicated. They have many tendons coming from the muscles in the lower arm. You can feel these tendons in your wrist and in the back of your hand.

Besides the muscles attached to the skeleton, there are many others. You know about some of them already. One type forms the wall of the heart. Another type is found in the veins, arteries, the stomach, the intestine, and the bladder.

There are three kinds of muscle cells, but they all have one thing in common. They are able to contract because they contain two special kinds of proteins. These muscle proteins are in the form of long, slender molecules lying side by side. When a signal reaches the muscle from the nervous system, the muscle contracts. The whole action includes some very complicated chemistry, but the general idea is quite simple. Carbohydrates break down by a special respiration process. This produces energy which is carried to the muscle proteins by ATP. This supply of energy causes protein molecules of one type to slide in between the molecules of the other protein. With millions of molecules all doing this at once, the muscle becomes shorter and thicker.

During exercise the rate of breathing and the rate of heartbeat speed up. The rushing blood carries the large amounts of food and oxygen needed for muscle contraction. The same blood carries away the large quantities of heat and carbon dioxide that are produced by the working muscles.

Regular exercise causes muscles to grow thicker. The thicker a muscle becomes, the stronger it is, so exercise increases strength. This growth in thickness is not due to cell division. The cell number stays about the same, but the amount of the muscle proteins increases. Each cell becomes larger and stronger. This is true of the heart, as well as of any other structure. Regular exercise keeps the heart in good, strong condition.

ACTIVITY

1. Bone is strong because it contains hard minerals bound together by flexible proteins. This is very much like fiber glass, which has glass fibers imbedded in plastic. You can demonstrate the presence of the two materials in bone in the following way:

(a) Place a chicken bone in dilute hydrochloric acid overnight. This will dissolve the mineral out of the bone and leave just the protein. What shape does the bone have after this treatment? Can you bend it?

(b) Place a piece of chicken bone on a wire screen and heat it steadily with a bunsen burner flame. This will burn the protein out of it, but the mineral will remain. What shape is the piece of bone after burning? Press it with your finger (after it is cool). Is it flexible?

2. If your school has a human skeleton, compare it with any other skeletons you can locate. Use pictures if necessary. Are most of the bones the same? What bones are present in one skeleton but not in another? Why is the connection between the hips and the backbone so much heavier in the human skeleton? Why are the human leg bones so much stronger than the arm bones? Do animal skeletons show these same differences? Explain. Notice the size of the face bones compared with the bones of the brain case. How do animal and human skulls differ in this respect?

CHECK YOUR FACTS

1. What are three functions of the skeleton? Can you see why a jointed skeleton is more important to a land animal than to a water animal?
2. What is the difference in the structure of bone and cartilage?
3. Where do we have cartilage in our bodies?
4. Name some bones that are used to make our movements more efficient.
5. Name some bones that protect body parts.
6. What is the structure of a movable joint?
7. A broken bone is considered less serious than an injured joint. Can you explain why?
8. In how many directions can a muscle move with power?
9. What gives muscles their ability to contract?
10. What is the difference between ligaments and tendons?
11. Explain how the elbow is bent and straightened. What other joints in the body are moved in the same way?

CHAPTER 44

The Ductless Glands

You have studied several glands already. You know how saliva, gastric juice, and pancreatic juice are produced by glands. You have studied the intestinal glands, oil glands, and sweat glands. A gland is an organ or tissue whose cells are specialized for manufacturing some particular material. In all of the glands just mentioned, this material flows out from the gland through a duct or other opening.

In this chapter you will study a special group of glands. Since they have no ducts, they are commonly called the ***ductless glands***. The cells of each ductless gland manufacture one or more special chemical compounds. The molecules of these compounds pass out through the cell membranes and are absorbed into the bloodstream. The chemical compound produced by a ductless gland is called a ***hormone*** *(hor-*mohn*)*.

Control of body activities by hormones. Since hormones travel in the bloodstream, they reach every part of the body. Some may have a chemical effect upon every body cell. Others influence only certain organs of the body. The hormones are chemical messengers. They regulate many important body activities.

Remember, we are made of trillions of cells. Some form of control is needed to keep all cells working together. The general rate of growth and cell activity should be kept in balance all through the body. The different organs of the body should perform their functions at the right times, so that they work well together. These are the kinds of things that are regulated by hormones.

There are a number of ductless glands in the human body. Some produce several hormones, some only one. Besides these, there are hormones produced by organs that we do not usually think of as being glands. For instance, the brain and the intestine lining are known to make hormones. In the rest of this chapter you will learn about a few of the better known hormones and of the glands that produce them. As you read about each gland, locate it in Figure 44-1.

The pituitary. The ***pituitary*** (pih-*too*-ih-ter-ee) ***gland*** is about the size of a cherry and is attached to the underside of the brain. It is one of the more

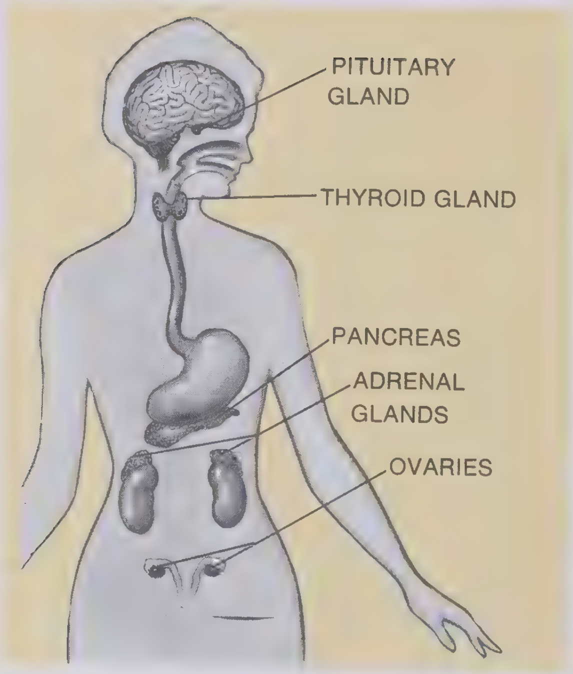


Fig. 44-1. Some of the ductless glands.

important ductless glands. It sends out at least ten different hormones many of which affect the activities of other ductless glands. Because the pituitary affects the action of other glands it has sometimes been called the "master gland." But the hormones of some other glands also have similar effects.

Besides those influencing other ductless glands there are pituitary hormones affecting the action of the kidneys, the blood vessels, the uterus, and the milk-producing glands. There is also a very interesting one called the ***growth hormone.*** The growth hormone stimulates body growth, especially the growth of the skeleton. The right amount of this hormone causes a person to grow to his normal size.

Once in a while the pituitary gland fails to produce enough growth hormone. This results in the kind of dwarf that is commonly called a midget. An adult midget three feet tall is considered small, but there have been 18-inch midgets. If the pituitary produces too much growth hormone, a giant will result. Giants may grow eight or nine feet tall.

The thyroid and parathyroid glands. The ***thyroid gland*** lies around the windpipe, below the voice box (Fig. 44-3). It produces a hormone that con-

Fig. 44-2. A giant and a midget, with people of normal height in the background. How can the action of hormones explain cases like this? (United Press International Photo)

Fig. 44-3. The location of the thyroid gland in the neck. What is its function? (Gabriele Wunderlich)

trols the rate at which all the cells carry on their chemical activities. In normal people it keeps all of the body cells working at about the right speed. Respiration rate is one of the activities partly controlled by the thyroid gland. If a doctor wants to check on this gland, he may use special equipment to measure how much oxygen the person is using when he breathes. In this way, he is indirectly checking on the activity of the thyroid gland.

A person with an overactive thyroid may have a large appetite but lose weight. His heart beats faster than normal, and he is nervous. Too much thyroid hormone is speeding up the chemical activities of the cells. In such cases doctors often remove part of the gland. A person with an underactive thyroid does not have much energy. He may become fat even though he does not eat much. The chemical activities of the body are slowed down because there is not enough thyroid hormone. Such cases are treated with pills which contain the thyroid hormone.

If a small child's thyroid fails to develop, he will become a feebleminded dwarf. If treated with thyroid hormone, such a child can develop normally. Of course the hormone must be given early enough so that growth can still take place.

The thyroid hormone is an iodine compound. In certain areas such as the Great Lakes region and the Pacific Northwest there is little iodine in the soil. Food grown in these regions does not supply enough iodine to the people, and thyroid disease once was very common. This situation has been changed by the use of *iodized salt.* This is ordinary table salt to which a little iodine is added. Shipping of foods from other regions also helps.

The fact that only the thyroid uses iodine has made possible an interesting use of radiation in medical treatment. Instead of removing part of an overdeveloped thyroid, the doctor may feed radioactive iodine to a patient. A radioactive element is one which gives off energy in a form similar to X-rays. Radium is an example of a radioactive element. Ordinary iodine is not radioactive, but the radioactive kind is made in nuclear reactors like the one at Oak Ridge. When this special iodine is first absorbed it spreads all through the blood. Not enough radiation goes to any one place to do

much harm. Very quickly the thyroid gland gathers in this radioactive material, just as it would any other iodine. So much radiation becomes concentrated in the gland that some of its cells die, and the thyroid activity is slowed down. Sometimes enough iodine is used to kill all of the thyroid cells. Cancer of the thyroid has been cured in this way.

How would a person receive thyroid hormone after his thyroid gland was gone?

The ***parathyroids*** are four small glands found on the back side of the thyroid gland. Their hormone is entirely different from that of the thyroid. This parathyroid hormone regulates the amount of calcium salts in the bloodstream. Normal amounts of these salts are needed for the muscles to relax. A shortage of the hormone leads to painful muscle cramps. Too much parathyroid hormone robs the bones of calcium, thus making them too soft.

Fig. 44-4. Diabetics soon learn to give themselves insulin.Some cases of diabetes can be controlled with pills. The doctor must decide which treatment is best for a diabetic. (New York Diabetics Association, Inc.)

The pancreas as a ductless gland. The ***pancreas***, as you know, is a digestive gland with a duct. It also contains small masses of a different kind of gland tissue. These are scattered throughout the gland and have no connection with the pancreatic duct. They produce a hormone called ***insulin*** *(in-suh-lin)*. Insulin is needed for the body to use its sugar normally.

As you remember, all of the carbohydrates that you eat are digested into simple sugars, such as glucose. When the glucose is absorbed from the intestine, only limited amounts stay in the blood. The remainder is stored in the liver and muscles until needed. Cells throughout the body take sugar from the blood and get energy from it through the process of respiration. Insulin is needed to help control both the storage of glucose in the liver and its oxidation in the tissues.

Diabetes (dy-a-*bee*-tis) is a common disease of the pancreas. It affects about one percent of the population. In diabetes there is not enough insulin produced. The liver and muscles fail to store sugar, and the body cells cannot use it. This leaves the blood flooded with sugar. This excess sugar is excreted in the urine. Frequent urination and thirst are two of the symptoms of diabetes. Loss of weight is another. Since the cells cannot use sugar for energy, they break down fats and even use protein from the protoplasm itself. The whole body

chemistry is so upset that the person is very sick.

Diabetics are given shots of insulin and a controlled diet. As long as they keep up this treatment they get along very well, leading normal lives. If you know a diabetic you can help by not tempting him to eat things he should not have. Also, you should understand a condition called *insulin shock*. Sometimes a diabetic may not eat enough to balance the insulin he has taken, or he may work harder than usual and use up his sugar too soon. There will then be too much insulin for the amount of sugar in his body. He will act as if he were drunk. He may even lose consciousness. This is insulin shock. At this time the diabetic needs sugar. Give him some carbohydrate food, such as candy, or bread.

The gland with two layers. The two ***adrenal*** (a-*dree*-nul) ***glands*** are located at the upper ends of the kidneys (Fig. 44-5). The outer layer of each adrenal gland produces a whole group of hormones which control several activities in the body. One of them affects the rate at which the kidneys do their work. Another influences the sex organs. Others affect the balance of dissolved salts in the blood. A failure of adrenal function will cause some salts to become scarce and others to become too abundant. The result is loss of weight, drying out of the tissues, weakness, and possible heart failure.

The center part of each gland produces a hormone that you may have heard about. It is called ***adrenalin*** (a-*dren*-a-lun). The amount of adrenalin produced rises in times of excitement. When large amounts of adrenalin pour into the blood, a whole set of changes prepare the body for action. The heart beats faster. Blood pressure rises. Blood flows in large amounts to the muscles and nervous system, but not to the skin or digestive organs. Digestion slows down. Breathing is deeper and faster. Sugar enters the blood.

The changes give the muscles the extra food and oxygen needed to do hard work. People under excitement often show strength they did not know they had. There have been cases where they lifted cars off accident victims, carried heavy loads out of burning buildings, and even killed leopards with their bare hands. Doctors use adrenalin to stimulate the heart when they fear it might stop. A shot of adrenalin may even start a heart

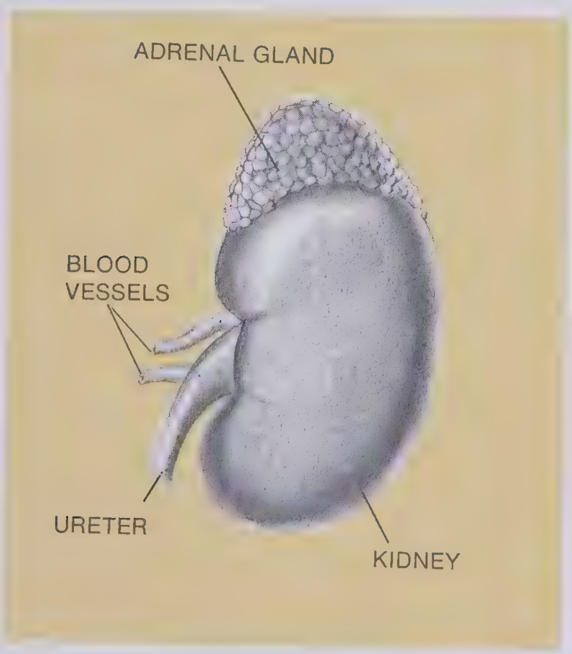


Fig. 44-5. The adrenal gland is located at the upper end of a kidney. There are two such glands—one on each kidney.

which has stopped beating. Adrenalin has also been used to relieve asthma attacks because of its ability to open the small air tubes of the lungs and to stimulate breathing.

The reproductive glands. The ***ovaries*** and ***testes*** produce eggs and sperms. They also produce what are known as the ***sex hormones.*** The testes produce male sex hormones and the ovaries produce female sex hormones. Two of the sex hormones are also produced in the outer layers of the adrenal glands, so everybody has some of each hormone. Males, however, have much more of one and females much more of the other.

The sex hormones have to do with the development and functioning of the sex organs. They also control the development of the ***secondary sex characteristics.*** These are the traits that are different in males and females, but are not directly concerned with reproduction. In some species these secondary sex differences are much greater than in others. For instance, you can recognize roosters and hens (male and female chickens) even at a distance. The rooster is much larger. He has brighter-colored, longer tail feathers. His comb is larger, and he has spurs on his legs. Behavior is different also. He crows, struts, and fights. Male and female bears, on the other hand, look very much alike except for size.

In man the secondary sex characteristics include such things as the deeper voice, larger size, and growth of beard in the male. The male body has more muscle and bone in proportion to its weight than the female body. Women have more fat under the skin layer. Differences in body proportions are also present, the male having broader shoulders and somewhat narrower hips in most cases.

The ductless glands in general. There are several more hormones that we have not mentioned. But those that you have studied are enough to show the importance of the ductless glands. In general, these glands keep the blood and lymph in just the right condition so that the cells can live and grow normally. The body must be an environment in which the cells can live. It is called the *internal environment.* All the hormones work together to keep this internal environment about the same at all times.

The hormones are not the only things controlling this internal environment. The liver, kidneys, and nervous system also affect it. In fact, the flow of the hormones themselves is often under nerve control. Notice that the pituitary gland is located in close contact with the master nerve center, the brain. You may also remember that the vitamins you get in foods have important effects upon the internal environment.

Diseases of the ductless glands. Whenever a ductless gland fails to work as it should, the internal environment of the body is upset. Then the cells cannot function normally. How this affects the person depends upon which hormones are involved. Giants and several kinds of dwarfs are the result of gland disturbance. Diabetes is another well-known example. Extreme fatness or extreme leanness can be results of gland trouble. Addison's disease, Cushing's disease, and goiter

are other gland diseases that you may have heard about.

Doctors now treat many of these troubles by using hormones. It should become possible to treat many others as more is learned about gland action. The study of hormones is difficult because one gland affects another. A certain result may be due to two or more hormones.

CHECK YOUR FACTS

1. **What is a gland? What is a duct?**
2. **What is a hormone? How does it leave the gland that produces it?**
3. **Give the function of each of the following glands: Pituitary, thyroid, parathyroids, pancreas, adrenals, reproductive.**
4. **What gland would you suspect was out of order in each of the following cases: (a) a person with little energy, (b) a thin nervous person with a pulse rate of 140, (c) a man two feet high, (d) a diabetic, (e) a giant?**
5. **What should you do for a diabetic friend who starts acting as if he were drunk?**

CHAPTER 45

The Nervous system

The nervous system controls the actions of the muscles and many actions of the glands. It acts with the gland system in regulating the internal environment. The nervous system also adjusts the individual to the outside environment.

In the study of behavior two words are very useful. They are ***stimulus*** (*stim*-yoo-lus) [plur. stimuli (*stim*-yoo-lie)] and ***response.*** A stimulus is something in the environment which affects the individual. Whatever he does because of this stimulus is his response. For instance, suppose you are crossing the road. You see a car coming, so you step back and let it pass. The sight of the car is the stimulus. Stepping back is your response.

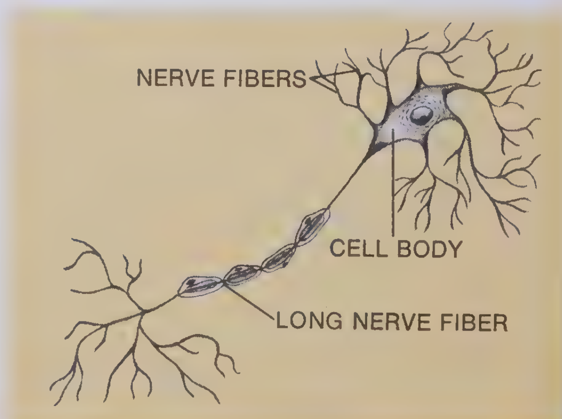
If a rabbit sees a car coming it also responds. It may run straight down the road, trying to get away. It does not step back to let the car pass. The rabbit's eyes see the car just as yours did, and it can move with its leg muscles even faster than you can. But the rabbit lacks your intelligence. It is not able to predict that the car will go straight down the road. Instead the rabbit responds as if the car were chasing it.

If a caterpillar were crossing the road it might not respond at all. It could not see the car coming, nor could it move fast enough to save itself from being killed. For the caterpillar, the car is not a stimulus.

As you see, responses are not all the same. Responses depend upon the ability of the sense organs to detect the stimulus; they depend on the intelligence of the animal; and they depend on how well the animal can use its muscles.

Nerve tissue. The cells of the nervous system are specialized to carry messages through the body. There are long strands called ***nerve fibers*** leading out from the main bodies of these cells. Figure 45-1 shows one kind of nerve cell. The shorter fibers at the right carry messages inward, toward

Fig. 45-1. A motor nerve cell.



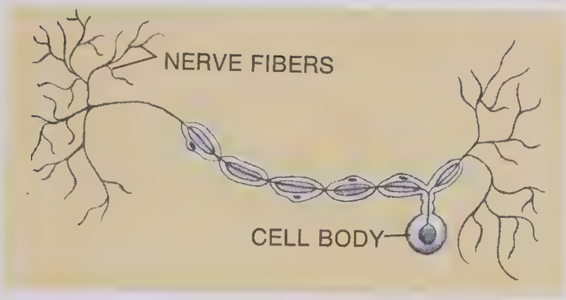


Fig. 45-2. A sensory nerve cell.

the cell body. The long fiber at the left carries messages outward, away from the cell body. The ends of this long fiber connect with several of the cells in a muscle. The muscle cells contract when the message reaches them. It takes many nerve cells to control the whole muscle.

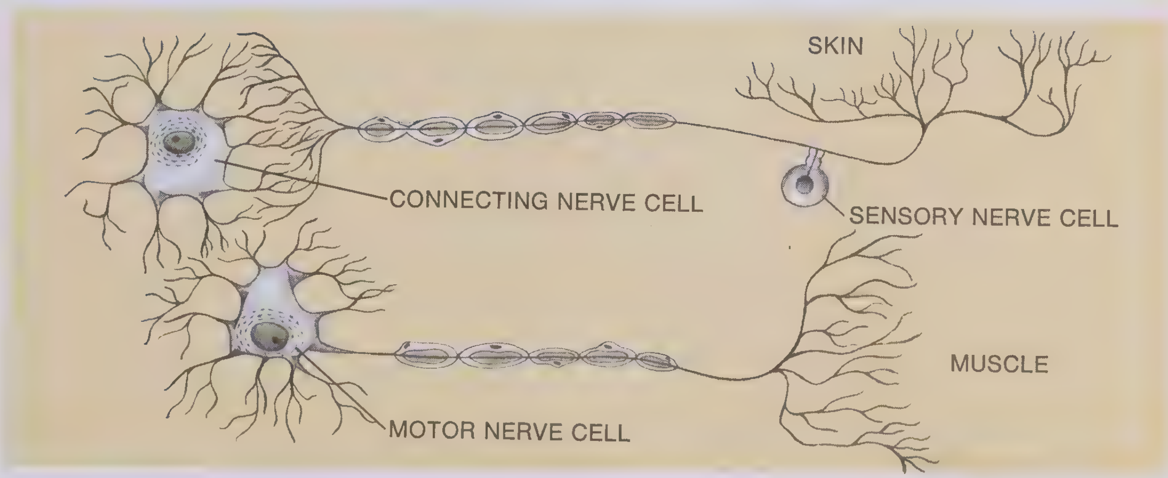
Nerve cells of this type are called ***motor nerve cells.*** *Motor* means mover. Motor nerve cells produce movement, or action. Motor cells control gland action as well as muscle action.

Motor nerve cells are just one of many kinds. Another common type is a ***sensory nerve cell.*** One of these is shown in Figure 45-2. This type brings messages inward from the sense organs. In Figure 45-2, the message would travel from right to left.

What we have called a "message" really should be called a ***nerve impulse.*** It is always the same in all nerve cells. It consists of a change in an electrical charge that travels along the nerve fiber. It is not an electric current, which would travel much faster. The rate at which a nerve impulse travels in man may be as low as $2\frac{1}{4}$ miles per hour or as high as 265 miles per hour. Its speed depends upon the size and structure of the particular nerve fiber. Oxidation of food materials in the cytoplasm of the fiber supplies energy to drive the nerve impulse along.

Figure 45-3, shows a motor nerve cell and a sensory nerve cell with a ***connecting nerve cell.*** These three kinds of cells work together to control action. To see how this works imagine that the long sensory fiber in the drawing is in your arm. At the right it ends in the skin of your finger tip. The long motor fiber ends in a muscle of the same arm. The cell bodies and the

Fig. 45-3. A circuit made up of three kinds of nerve cells. What kind of response can be controlled by such a circuit?



fibers are in your neck. In other words, single nerve fibers reach the entire length of your arm. Nerve cells are the longest cells known. But the fibers are so slender that you cannot see them.

A mass of nerve cell bodies is known as a ***nerve center***. The nerve fibers leading out from a nerve center are grouped together in bundles with a sheath around them. Such a bundle is called a ***nerve.*** A large nerve may contain many nerve fibers.

An automatic response. What happens in the nervous system when you accidentally touch a hot iron? The heat of the iron injures the outer end of a sensory nerve cell fiber. This causes a nerve impulse to pass through the long fiber and out to the ends of the short fibers. This starts an impulse in a connecting nerve cell, which in turn starts one in a motor cell. The impulse speeds along the motor fiber to the muscle, causing it to contract. The contracting muscle jerks your finger away from the iron. It all happens in a small fraction of a second. Actually, of course, there are many of each kind of cell working at the same time, but our simple diagram (Fig. 45-3) shows only one of each kind. A quick, automatic response like this is called a ***reflex.***

Nerve cells in the nerve center are already set up to cause a reflex in this particular way. You do not think about it before you move. You discover afterwards that you have moved. The kind of response that is made depends on which way the nerve impulses travel from cell to cell.

When you burn your finger, you jerk it back even before you feel pain. Nor do you know that you have responded. Remember, reflexes are automatic. A nerve center in your neck controls this reflex. Meanwhile, other nerve fibers carry impulses up to the brain and start activity in the brain cells. Then you become conscious of pain and also of the fact that you have jerked your hand back. The brain may then direct your muscles in some conscious responses—responses like saying "ouch," shaking your hurt finger, and shouting remarks about the kind of people who leave hot irons lying around.

We have reflexes, including those that blink the eyes, those that jerk hands and feet, and those that cause muscles to tighten when they are stretched. These stretch reflexes keep the muscles tense enough to hold us erect even when we are not thinking about it. The movements of muscles in the internal organs are also reflexes.

All conscious responses are controlled by the brain. The brain is a great mass of nerve centers, all affecting one-another. Some reflex responses are controlled by centers in the spinal cord. Some depend upon centers in the back on either side of the spinal cord. Others are directed by centers in the brain.

How does one nerve cell start a nerve impulse in the next nerve cell? Scientists wondered about this for a long time. Now they think they know the answer. Our nerve cell diagrams (Figs. 45-1, 2, 3) have not shown the smallest divisions at the ends of the nerve fibers. They were finally discovered with the help of the electron microscope. They are very numerous and very tiny.

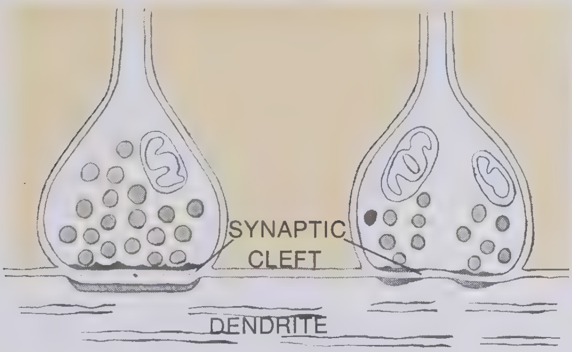


Fig. 45-4. The last, tiny divisions of nerve fibers making contact with a nerve cell. How might other nerve cells influence this one?

Figure 45-4 shows a dendrite of one cell. It also shows the ends of two nerve fibers that come from other cells. See how each one has a little flat end pressed against the surface of the dendrite. Cell membranes separate the cytoplasm of the cell from the cytoplasm in each of these fibers. If a nerve impulse arrives at the end of one of the fibers it causes a chemical compound to be produced between the two cell membranes. This compound causes a new nerve impulse to start in the next cell. Then the compound is immediately destroyed by an enzyme, and the way is clear for a new nerve impulse to come through.

This is the way scientists now believe that nerve impulses travel from cell to cell. Notice that one cell may have contact with hundreds of other cells, so there are all sorts of different pathways a nerve impulse may follow. This is why so many different kinds of responses are possible.

The organization of the nervous system. The central part of the nervous system consists of the *brain* and *spinal cord.* The spinal cord lies along the back. It connects with the brain through a large hole in the base of the skull. Together, the spinal cord and brain contain about 10 billion cells organized into many nerve centers. These centers connect with one another by means of nerve fibers.

From the brain and spinal cord nerves pass out to all parts of the body. Most nerves coming from the brain connect with parts of the head and face. Those from the spinal cord connect with all parts of the body. Injury to the spinal cord is very serious. If it is destroyed at the neck level, the internal organs lose their nerve connection with the brain. Death results. If the injury is lower, the legs may become paralyzed. This is why moving an injured person must be done so carefully. Cracked vertebrae can cut the spinal cord. Polio cripples people by killing motor cells in the spinal cord.

Besides the nerve centers in the brain and spinal cord, there are others in the chest cavity and abdomen. They lie on both sides of the backbone. The function of these centers is to help the centers in the brain and spinal cord control the internal organs. You have probably had your "wind knocked out" at some time. The blow had jarred nerve centers which help to control breathing. The diaphragm was temporarily paralyzed.

The entire organization of the nervous system is very complicated, but by now you should have a general idea of what it is like. There are controlling centers in the brain, spinal cord, and elsewhere. These connect with one another and with all parts of the body. The whole system works to-

gether to receive sensation, make decisions, and control responses.

The brain. There are three main parts of the brain that can be seen from the outside. They are the *cerebrum (sehr*-uh-brum*)*, the *cerebellum* (sehr-uh-*bel*-um), and the *medulla* (muh-*dul*-a). Figures 45-5, 45-6, and 45-7 show the ***cerebrum***, which is by far the largest part. In lower vertebrates this is not true. The cerebrum of a frog or a fish is very small. The more intelligent animals have larger cerebrums. In man, the cerebrum surface is very much folded. This is important because the outer surface of the cerebrum is made up largely of nerve cell bodies. The folding greatly increases the amount of surface. There can be many more nerve cell bodies than there could be in an unfolded surface. Similar folding of the cerebrum is found in other mammals. But this folding is generally not as extensive as it is in man.

Cells near the surface of the cerebrum have fibers that lie deeper down in this structure. Some of these fibers connect with other centers in the cerebrum. Some of them connect with centers in other parts of the brain. Some of them pass out of the brain to other parts of the body. Others connect centers in the cerebrum with centers in the spinal cord. The whole cerebrum is a marvellous structure for receiving nerve impulses and putting them together in all sorts of combinations. In some way that we do not understand, this all adds up to make what we call the human mind. Memory, thinking, and consciousness are all functions of the cerebrum.

The cerebrum receives nerve im-

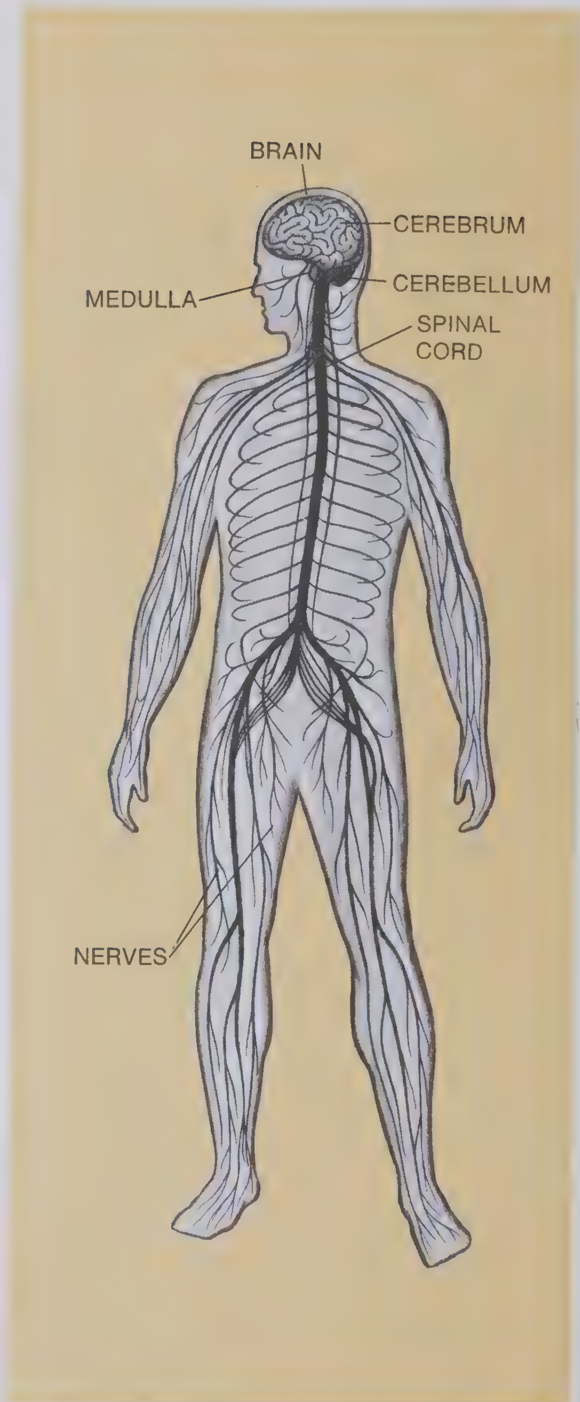
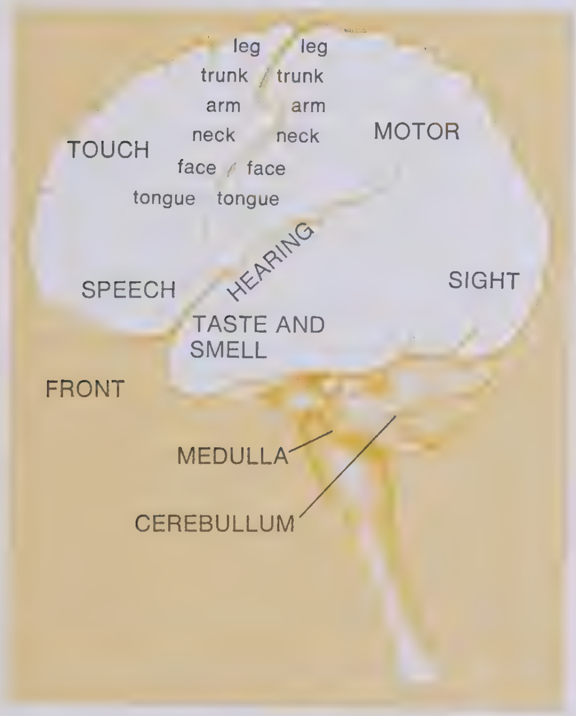


Fig. 45-5. The human brain, spinal cord, and the main nerves.

Fig. 45-6. The human brain, cut down the center. (Joseph James)



pulses from the sense organs. It considers what they mean and compares them with past experience. It decides what responses should be made and sends out the proper motor impulses to the muscles. This is another way of saying that the cerebrum controls our conscious responses to the outside environment.

Various parts of the cerebrum have special functions. Some of these are shown in Figure 45-7. Certain *sensory centers* receive particular sensations. Other *motor centers* control muscular movement. Still other centers interpret sensations. Thus, one sensory

Fig. 45-7. The brain works as a whole unit, but some parts of it have special functions.

center receives incoming impulses. Other centers interpret these impulses. Still others decide what to do. Then the motor centers send out impulses that cause the responses to be made.

The ***cerebellum*** helps the cerebrum to control the muscles and also helps to maintain our sense of balance. Cooperation among the muscles would be impossible without the cerebellum.

The actions of the ***medulla*** are automatic and unconscious. It helps to control breathing, heartbeat, and blood pressure. It has reflex centers for coughing, sneezing, swallowing, and the production of saliva. It is also a pathway between the spinal cord and the rest of the brain. As you can see, the medulla is a very important part of the brain.

Types of responses. Some responses are learned, and some are unlearned. The simplest unlearned responses do not even require a nervous system. Green plants, for instance, respond to light and gravity. You have seen how a potted plant bends and grows toward a window. Such responses are controlled by hormones. The growth hormone of the plant is destroyed by light. This leaves more of the hormone on the dark side of the stem. That side grows more rapidly than the other, turning the plant toward the light.

Reflexes are the simplest responses controlled by nervous systems. Most movements of *Hydra* are reflexes. Its nervous system is just a loose network of nerve cells. There are no nerves or nerve centers.

We use the word ***instinct*** to describe unlearned behavior that is more complicated than a simple reflex. But reflexes and instincts are really just different degrees of the same thing. In both cases, the animal inherits a nervous system that is already set to respond in a certain way to a certain stimulus.

Nest building in birds is a good example of instinct. Suppose you were to hatch a robin's egg in the house, without a nest, and raise the young bird as a pet. If you freed this robin the next spring, it would probably mate and build a regular robin's nest of mud and grass. Since the bird had never seen a nest before, we could be quite sure that its nest building was the result of instinct.

All animals except man have well-developed sets of instincts for surviving in their natural environments. They have inherited nervous systems that are all set to respond correctly. Their instincts are used to obtain food, escape from enemies, and reproduce.

Learned responses. The more intelligent an animal is, the more it can learn. In vertebrates the most intelligent animals have well-developed cerebrums. Not much brain tissue is needed to control automatic responses. Much more is needed for learned responses. Man's cerebrum enables him to learn more than any other species.

In animals learning is often a matter of adjusting reflexes and instincts to local conditions. A chicken, for instance, has an instinct to roost at night, but it must learn which particular roost to use. Wild dogs have instincts for hunting, defending the home range, and accepting leadership within the pack. Your tame dog

has these same instincts, but through learning, he applies them to local conditions. Your family is his "pack." His master is the "lead dog." Barking at strangers is defending the "home range."

In man this ability to modify instincts has gone so far that it is hard to prove that he has any real instincts left. Of course man does have many simple inherited responses. Babies eat, cry, squirm, and fear loud noises. These are some simple instincts of man, but there are no complex ones such as the nest building of birds or the social behavior of ants and bees. Man must learn in order to survive. Food getting, escaping from danger, and social customs are all learned.

Basically, learning depends upon *experience*, *memory*, and *emotion*. When you are faced with a problem, your response will depend partly on past experience with the same problem. Let's say that the first time you use a certain tool you cut yourself. The memory of this past experience will cause you to hold the tool differently the next time. Notice how emotion affects learning. Getting cut was unpleasant, and made you wish to avoid the same trouble.

In the same way, pleasant memories make us wish to repeat some responses. A little boy may refuse to eat an ice cream cone the first time he sees it, but after tasting it, he will not refuse again.

When a response has been repeated over and over again the result is a *habit*. The pathway of the nerve impulse has been so firmly established that it goes that same way from then on. Good habits are very useful. They enable us to respond automatically to familiar situations. This leaves our conscious minds free to deal with new stimuli as they come along.

You would be helpless without your habits. All of the ordinary motions you make in sitting, walking, dressing, eating, and writing are done mostly by habit. A well-established habit is like an instinct. It is done without thinking. Of course you can also develop habits that are handicaps. For instance, you can start out by holding a baseball bat in some awkward way. Later, you have to form a new habit to take the place of the old one.

Intelligence is the ability to learn. The more intelligent animals not only learn more things, they learn more complicated ones. In man intelligence is not a single quality. A person may have high mathematical intelligence and low musical intelligence. If such a person is in school he probably gets high marks in his mathematics class and low ones in music. Ability in music, mechanics, mathematics, language, logical thinking, and social understanding are all parts of intelligence. Very few people are high in all of them. You probably have discovered that you are much better in some things than in others. Most "intelligence tests" do not measure the whole intelligence. They are used simply to find out what a person's abilities are for doing school work.

You have probably noticed, however, that some people seem to be much more intelligent than others. What makes people different in this way? Our best guess is that intelligence depends partly on heredity and partly on environment. After all, genes control the physical structure of the

Fig. 45-8. Gannets building a nest. What reasons can you give for thinking that this procedure is an instinct rather than learned behavior? Is any of it learned? (Grant Haist)

brain, so we can expect some people to inherit better brains than others. On the other hand, a person only learns to use his brain through practice. If he does not have this practice, he may seem to be stupid even though he inherited a perfectly good brain. Often people think they cannot learn something so they do not try. They fail to develop their full intelligence. A person living in an environment where he is encouraged to be curious and to learn will develop his learning ability. He will seem to be more intelligent than someone else who developed in a different environment. But he may not really be. The other person may have inherited equally good brain structures that he has not learned to use. In his environment he was not challenged to use his full powers. Can you see now why we say that intelligence depends partly on environment?

Mental defects and mental disease. Sometimes the nervous system fails to work as it should. The person may be *feebleminded*. This means his intelligence is like a child's even when he is grown. *Insane* persons fail in some way to recognize the difference between what is real and what is not. *Neurotic* persons are disturbed emotionally. Ordinary situations upset them more than they should. There are special doctors called *psychiatrists* (sy-*ky*-a-trists) who are trained to treat insane and neurotic people.

Do not try to play psychiatrist if someone you know seems to have a mental problem. After all, you may be wrong in thinking he has. You are not an expert. Never tell him he is crazy. That will just make matters worse. Talk to your doctor about the situation. If he thinks there is a real problem, he will tell you where your friend can receive expert help.

ACTIVITY

Two experiences with the nervous system. From the butcher get the brain of a calf, pig, or sheep. Notice that the cerebrum is the largest part. Would this be true for all animal groups? Notice how the cerebrum surface is folded. This gives more room for cell bodies in the important surface layer. Locate the cerebellum and the medulla. What are their functions?

Let one student hold a sheet of strong plastic in front of his face. Have another student throw paper wads at the plastic. Can the one behind the plastic keep from blinking when the wads come toward him? What sort of a nervous response is this?

CHECK YOUR FACTS

1. What does the nervous system do for us?
2. What is meant by stimulus and response? Give examples (try to think up some of your own).
3. What are three general kinds of nerve cells? How do they differ?
4. What is a reflex? Would it be better to have no reflexes and to use only conscious responses? Why?
5. What are the parts of the nervous system?
6. What are the parts of the brain? What does each part do?
7. What are instincts? What evidence can you think of to show that most human behavior is not instinct?
8. How do we learn?
9. What is habit? Is it good or bad? Why?
10. What is intelligence? Why do some people have higher intelligence than others?

CHAPTER 46

The Sense Organs

There once was a mother who became worried about her small child. He leaned his hand against a hot stove and laughed. His hand was badly burned, but he did not mind at all. Tests showed that this little boy was normal in every way but one—he had no sense of pain.

Maybe you think that would be a wonderful thing. But consider that if this child had felt pain he would have jerked his hand away quickly. His burn would not have been so serious. The next time he would not have touched the stove at all. Pain is a good teacher. It trains us to avoid things that would damage our bodies. This child was always in danger of getting bad injuries from burns, cuts, falls, and other accidents. Teaching him not to damage himself was not a very easy thing to do.

The sense of pain is one of the ***special senses.*** This little boy's case shows how important the special senses are. Blindness and deafness are other examples of the loss of a special sense. One function of the nervous system is to adjust the individual to the environment. The nervous system does this through the process of stimulus and response, and a stimulus is received through the senses.

The special senses of man are the senses of *sight, hearing, balance, smell, taste, touch, pressure, heat, cold, pain,* and *muscular effort.* In most cases there is a sense organ for each kind of sensation. Sensory fibers carry impulses from these sense organs to the nerve centers. The cerebrum has different sensory centers for receiving the impulses coming from each of the sense organs.

The skin senses. The skin contains four kinds of tiny sense organs. They are organs of touch, pressure, heat, and cold, as shown in Figure 46-1. In each one the nerve fibers are surrounded by a little capsule of special cells. Notice that there is no capsule around the nerve endings that detect pain. They are simply nerve endings in the tissues. Many of them are in the skin, but you also have them in other parts of the body.

The chemical senses. Smell and taste detect the presence of chemicals. In the case of taste, the chemical must be dissolved in the mouth before it is sensed. In the case of smell, the chemical molecules must be in the air. These enter the nose during breathing. When liquids evaporate, their

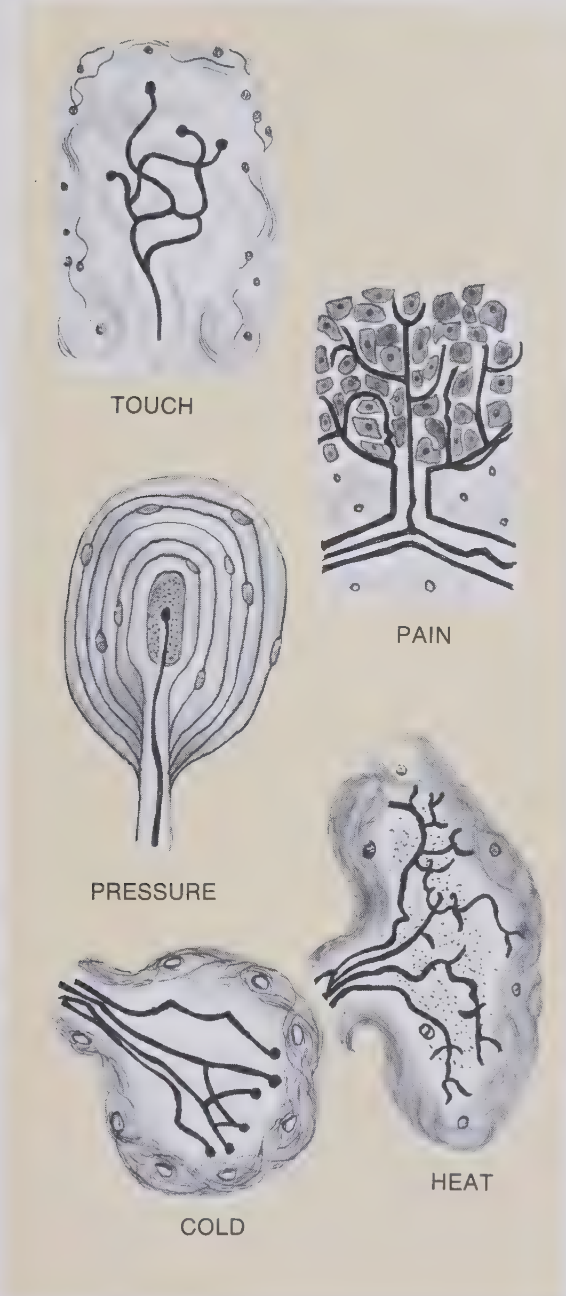


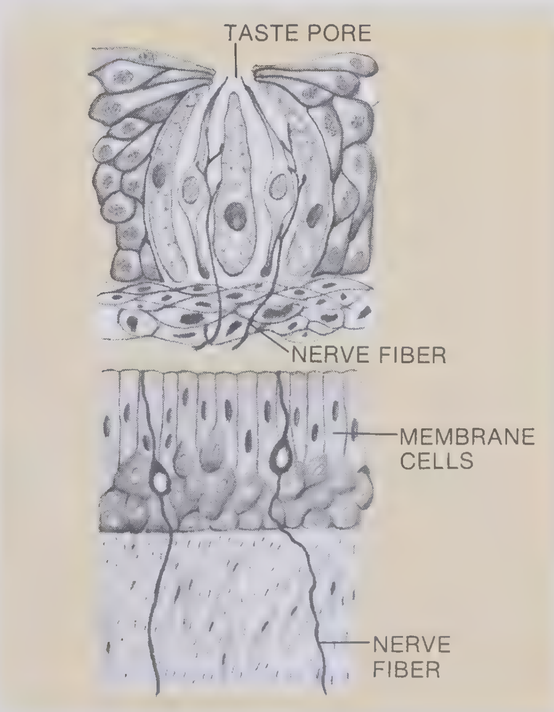
Fig. 46-1. Five kinds of sensory nerve endings in the skin.

molecules enter the air. Many solids also lose a few molecules to the air. We can smell some of them.

The sense of smell results from the action of gas molecules upon nerve cells in the lining of the nasal passages (Fig. 46-2). Molecules of chemicals become scattered about in the air. When they enter our noses we get the sensation of smell. No one is sure just how many odors we are able to detect. It may be that there are just a few basic ones and that all others are combinations of them.

Our sense of smell is poor when compared with other mammals. We use it mainly to help us select and enjoy our food. Most mammals have a very keen sense of smell. They use it to detect things at a distance. A deer can smell another animal several hundred feet away if the wind is right. Dogs can

Fig. 46-2. Sense organs for taste and smell. The top diagram shows a taste bud on the tongue. The bottom diagram shows the sensory cells which detect odors. They are located in the membrane that lines the upper part of the nasal passage.



smell the ground and tell if a rabbit has passed that way. They can follow the rabbit's trail.

The sense of taste is due to the work of special cells in the mouth. They come in clusters, and each little cluster is contained in a tiny pore in the tongue or the mouth lining (Fig. 46-2). These taste cells are not nerve cells, but the ends of nerve fibers connect with them. The whole structure is called a ***taste bud.*** The cells in the taste buds are affected by certain kinds of molecules in such a way that nerve impulses are sent to the brain. There they register as taste.

There are only four flavors that can be detected by the taste buds. They are sweet, sour, bitter and salty. Of course more than one may be present at once, giving a combination flavor. Much of what we think is the taste of foods is actually odor. We smell the food while we chew it. Smell and taste blend together to give the complete flavor. Next time your nose is stopped up with a cold, notice how tasteless some foods are.

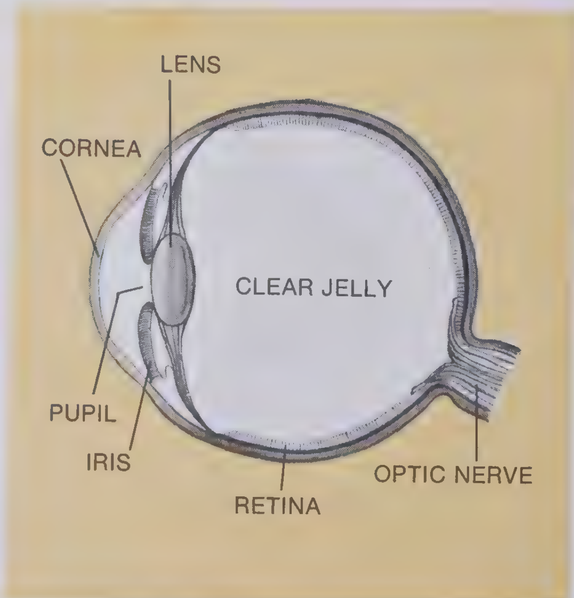
The sense of muscular effort. This sense comes from nerve endings in the muscles and tendons. If you hold your arm out sideways, you can feel its position without even looking. This ability to tell your own position in space is very useful. It is needed in order to move accurately, when walking, jumping, or reaching out for things.

The sense of sight. Eyes are organs that detect light. Light reflects from all the objects around you. This reflected light enters your eyes and enables you to see those objects. Most animals can sense light. An earthworm "feels" light with its body surface. Remember the eye-spots of *Planaria?* One-celled animals like *Ameba* and *Paramecium* also respond to light. None of these animals can see objects. They are only able to tell light from dark.

Only three groups of animals have eyes that can detect the shapes of things. These animals are the squid class of mollusks, the arthropods, and the vertebrates. The arthropods have compound eyes (Chapter 32). The eyes of the squid and those of the vertebrates are very much alike. In both types of eyes there is a *lens* to form an *image*, or picture, upon a *retina (ret*-uh-nah*)*.

The ***retina*** is a layer of nerve cells that are sensitive to light. Figure 46-3 is a diagram of the human eye. If you study it you will see that the retina lines the inside of the eyeball at the back. The only way light can reach

Fig. 46-3. The main parts of the human eye.



the retina is by coming in through a curved "window" in the front of the eye. This structure is the *cornea (kor-nee-uh)*.

The cornea is clear, like glass, and its surface is curved, like a magnifying glass. This curved surface of the cornea acts as the main lens of the eye. Inside the eye is the part called the ***lens***, and this lens works with the cornea to form an image on the retina at the back of the eye.

We make practical use of the image-forming power of lenses both in cameras and in projectors. An image is formed on the film of a camera. The image of a projector is formed on the screen.

The nerve cells of the retina connect with the brain by way of the ***optic nerve.*** Each cell of the retina "reports" on the lightness or darkness of the particular part of the image that falls upon that cell. In the brain these thousands of "reports" are combined, and the person becomes conscious of what he is seeing. Blindness can result from damage to the eye, the optic nerve, or the sight centers in the brain. Each of them has its part in the act of seeing an object.

A lens cannot form a clear image of near and far objects at the same time. In a camera, the lens is moved closer to the film to photograph distant objects and farther from it for nearby objects. This is called ***focusing*** the camera. The eye focuses in a different way. It changes the shape of the lens. For seeing nearby objects the lens becomes thicker and more curved. For distant objects it flattens out into a less curved form. There is a ring of muscle fibers around the lens which does this focusing. When these muscles are at rest, the eye is focused for distance. When they contract, it focuses on nearby objects. This is the real function of the lens in the eye—to focus on nearby objects. The cornea has most of the lens power of the eye and it does most of the image forming.

Defects of the eye. *Nearsightedness* is a condition in which there is too great a distance between the lens and the retina. When people with such eyes look at a distant object, the image comes to a focus in front of the retina instead of on it. The light reaching the retina is out of focus, and the person sees a fuzzy image. This condition is helped by wearing glasses with *concave* lenses in them. These lenses are thinner in the center than at the edges. They spread out the light before it reaches the eye. Then the light rays take longer to come to a focus, and they produce a clear image (Fig. 46-4).

Farsightedness is just the opposite. The distance between the lens and the retina is too short. The image is not yet fully formed when it reaches the retina. Such eyes cannot see nearby objects clearly. They are helped by *convex* lenses, which are thicker in the center than at the edges. They bring the rays of light closer together before they reach the eye (Fig. 46-4).

Astigmatism is a condition in which the eyeball is a little out of shape, and it also forms an image which is out of shape. This makes small things hard to recognize at a distance, and the person may think he is nearsighted. If one eye has a different amount of astigmatism from the other there is a feeling of eyestrain. Head-

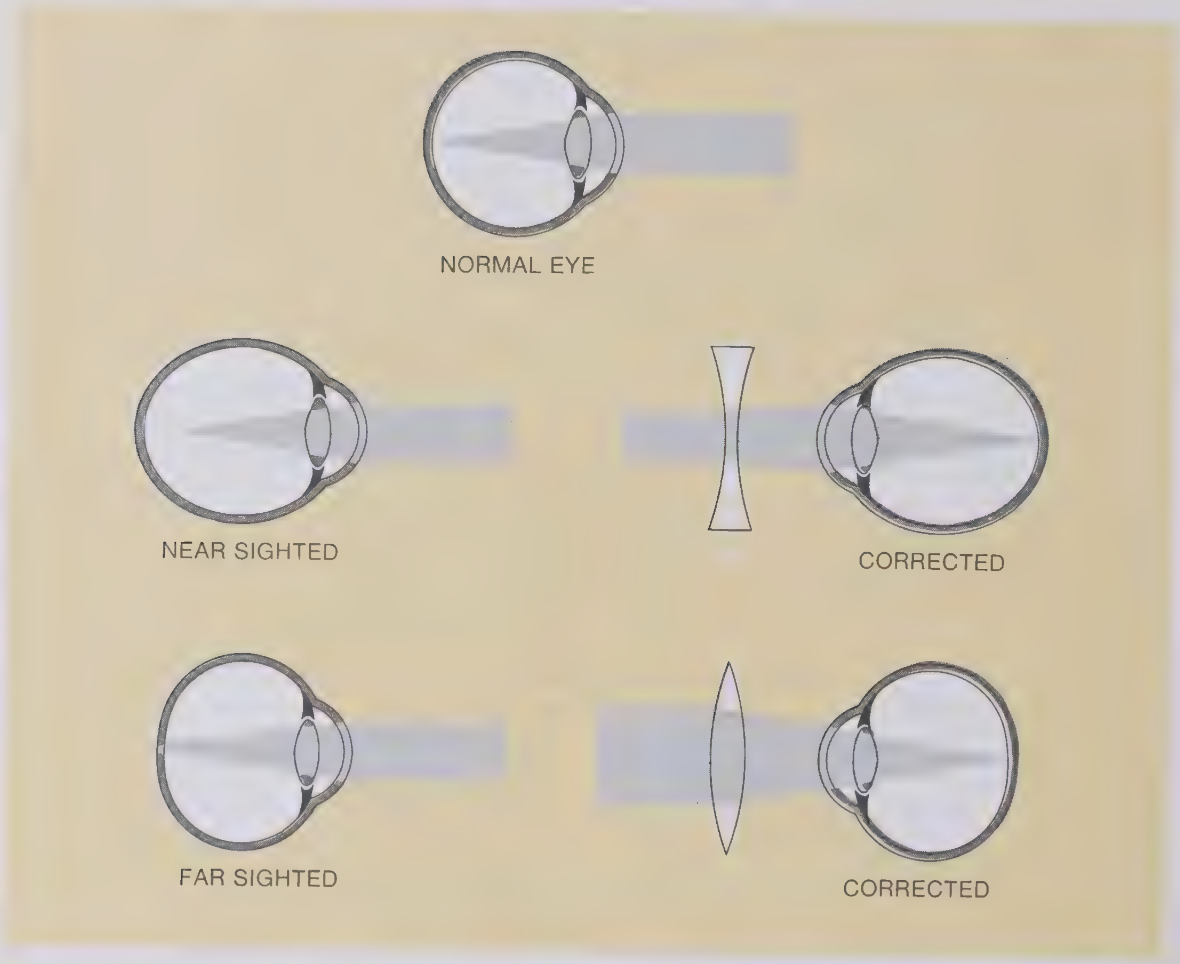


Fig. 46-4. The correction of eye defects by means of glasses.

aches may result. To correct astigmatism we use lenses with a lopsided curve that is just right to correct the out-of-shape image produced by the eye.

People often develop a form of farsightedness sometime after the age of 40. This is because the lens begins to lose its ability to change shape. It can no longer become thicker and more curved for seeing nearby objects. Such people must often hold a page at arm's length in order to read it. Reading glasses help to correct this condition. They have convex lenses and are used only for reading or other close work. Bifocal glasses have two parts to the lenses. The upper part is for seeing things at a distance, and the lower part is for reading.

Other eye structures. Just in front of the lens is a partition with a hole in the middle. This partition is the ***iris*** *(eye-*ris*)*, the colored part of the eye. The hole in the iris is the ***pupil.*** The iris is muscular, and it controls the size of the pupil. In this way the amount of light entering the eye is regulated. In dim light, the muscles

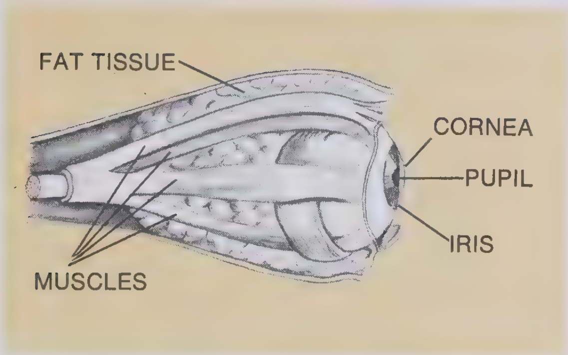


Fig. 46-5. The muscles that move the eyeball.

of the iris open the pupil wide, allowing more light to enter. In bright light, the pupil becomes small. This protects the sensitive retina from contact with too much light.

The inside of the eye is filled with a clear jelly. It is under enough pressure to stretch the tough outer covering and hold the eyeball in shape. The bones of the skull protect the eye on all sides. The eyelids blink shut to protect the front. They also spread the tear fluid across the surface. This fluid comes from the tear gland under the upper edge of the eye socket. It washes out dirt and protects the eye against germs.

The eyes are moved in their sockets by six small muscles attached to the outside of each eyeball (Fig. 46-5). These muscles keep both eyes looking at the same object. Although each of our eyes forms an image, our brain puts the two images together, so that we see only one picture. The slight difference between the two images is interpreted by the brain in a special way. It tells us whether an object is nearby or far away.

Care of the eyes. The eyes you have now are the only ones you will ever have. Take care of them. If they pain you or fail to see well go to a doctor. If he prescribes glasses, use them. Look out for injury to the eyes. Avoid looking directly at the sun or other very bright light. Keep sharp objects like knives and pins away from the eyes. If you work on grinding machines or other high speed tools use safety goggles to keep flying bits of metal out of the eyes. If you wear glasses it is a good idea to pay a few dollars extra to get hard glass lenses. These have saved many people from being blinded by accidents.

The sense of hearing. Sound is caused by the rapid vibration of some material. Sound can travel through air, water, steel, rock, and many other materials. Our ears are adapted to hear sound in air. When you slap the top of a table, air molecules in the area are disturbed. They hit other molecules which in turn hit more molecules. This disturbance of the air molecules moves outward in all directions in what is called a *sound wave*. Someone at the far end of the room hears a sound because a membrane in his ear is caused to vibrate by the advancing sound wave. The pitch of the sound depends on the rate of the vibration of the molecules.

The human ear is divided into three regions—the *outer ear*, the *middle ear*, and the *inner ear* (Fig. 46-6). The outer ear includes the part of the ear that can be seen on the outside and also the passageway into the head. A thin membrane stretches across the inner end of this passageway. It is called the ***eardrum***. The hollow space behind the eardrum is the middle ear. The inner ear is made of curving passages of hol-

low bone tubing. It lies in a bone of the skull, back of the middle ear.

The first part of the ear to respond to sound waves is the eardrum. The sound waves bounce against it, making the eardrum itself vibrate. The eardrum is connected to the inner ear by way of three tiny bones which are hinged together. They reach across the middle ear and carry the vibration to the inner ear.

The hearing part of the inner ear is coiled and looks like a snail shell. This is called the ***cochlea*** *(**kok**-lee-a)*. The end bone of the middle ear bones vibrates against an opening in the wall of the cochlea. This causes the liquid inside the cochlea to vibrate. A row of special cells lies inside the cochlea. Sensory nerve cells connect with these special cells. Sensory nerve fibers connect with the brain by way of the ***auditory*** *(**aw**-di-tor-ee)* ***nerve***.

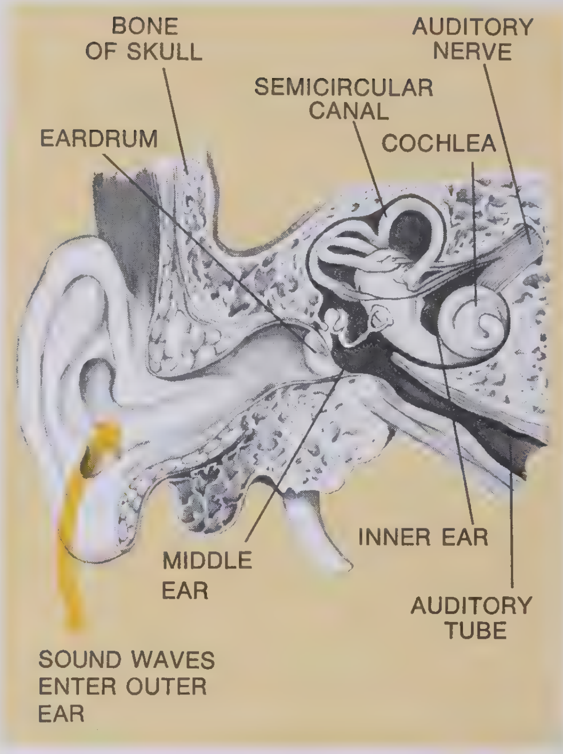


Fig. 46-6. The main parts of the human ear.

Remember that the pitch of a sound depends upon its vibration rate. A slow rate of vibration gives a low pitch. A rapid rate gives a high pitch. Each special cell in the cochlea responds to a different pitch. Each reports to the brain by way of its connecting nerve fiber, which passes along the auditory nerve. Most sounds stimulate several of these nerve fiber endings at once; but a musical note has a fixed vibration rate, so we hear it as a definite pitch.

The pressure of the air around us is not the same at all times. This could cause trouble for the eardrum if the ear had no way of adjusting to the changes. High pressure would push it in. Low pressure would allow it to bulge out. Damage to the eardrum could result. This is prevented by a passageway which connects the middle ear with the top of the throat, just back of the nasal passages. Whenever you swallow or yawn or shout, the end of this passageway opens, allowing the outside and inside pressures to become equal.

Care of the ears. Hearing can be damaged by too much loud noise. Working next to a drop forge or trip hammer day after day can make a person hard of hearing. Target practice with high-powered rifles or with pistols can have the same effect. At such times it is wise to protect the ears with ear plugs.

Ear infections can damage hearing. Germs present in the throat during a cold may pass up into the middle ear. When this happens the germs grow in the middle ear and produce pressure on the eardrum, causing an earache.

A doctor can usually stop such an infection, and it is important that people go to him at such times. Ear infections can cause permanent scarring of the eardrums and make the person hard of hearing.

It is very common for older people to become hard of hearing. They are especially apt to lose the ability to hear the higher tones. A hearing aid may or may not correct the condition. It depends upon the type of deafness. Being even partly deaf shuts people off from their friends. They miss most of what is being said. They annoy others by asking to have things repeated. Wearing a hearing aid is really not much different from wearing glasses.

Before getting a hearing aid, a person should see his doctor. Some treatment may be needed to keep the deafness from getting worse. In any case, the doctor can give advice on just what kind of hearing aid will be best.

The sense of balance. Besides the cochlea, the inner ear also contains a small round, hollow space and three tubes which curve around in half circles: the ***semicircular canals*** (Fig. 46-6). These structures are not involved in hearing. They are organs of balance. The round hollow space is lined with sensitive cells. In the middle are small rock-like particles of mineral. The weight of these mineral particles causes them to press down on the sensory cells. Nerve impulses from these cells make it possible for the brain to tell if the body is upright.

The semicircular canals give us the sensation of movement. They are filled with liquid, and they have nerve endings at each end. When the head is turned, liquid rushes to one end of the canal, pressing on the nerve endings. Turning the other way presses the liquid against the opposite nerve endings. The three canals are laid out in the three directions the head can move—sideways, nodding, or turning. No matter which way the head is turned, one or more nerve endings will be stimulated. The brain sends impulses to the muscles so that the person stays upright and does not stumble.

ACTIVITY

Observing the eyes. 1. You may look at your own eyes in a mirror, or two students may observe one another. Place your hand over one eye and then remove your hand. Watch the size of the pupil in the uncovered eye while you are doing this. The nerve controls for the two eyes are linked together, so putting one eye in darkness will cause both to respond. What change takes place in the size of the pupil? What is the function of this eye response?

2. Obtain animal eyeballs from the butcher. Freeze some if you have a refrigerator available. The frozen ones may be split open from front to back. The parts will stay in place so that you can see them in their natural positions. Unfrozen ones may be dissected carefully to locate the parts. Notice how tough the outer covering is. Notice the jelly inside which holds this

outer covering in shape. The retina will look like a thin silvery film in the back of the eye. Notice the lens and iris. The cornea and lens may be cloudy in your specimen, but they were clear when the animal was alive. Locate the place where the optic nerve connects with the back of the eyeball. What is its function?

3. Hold an ordinary magnifying lens in front of the wall on the side of the room opposite the windows. If you hold it just the right distance from the wall you will see an image of the window projected onto the wall by the lens. This works best if the room lights are turned off. Turn them on again and see how your lens can throw an image of each light onto a sheet of paper on your desk top. It is this same image forming power of a lens that is used in our eyes. What parts of the eye serve as a lens system? Where is the "screen?"

CHECK YOUR FACTS

1. **Suppose you had the best brain in the world but no sense organs. How would this affect you? How much could you accomplish?**
2. **What sensations do we get through our skin?**
3. **What form must materials be in before we can taste them? Smell them?**
4. **Why do we need sensory nerve cells connecting with our muscles and tendons?**
5. **Describe the process of seeing and name the parts of the eye that do the job.**
6. **Which kinds of lenses correct various eye defects?**
7. **What part of the ear first responds to a sound wave?**
8. **What part of the ear does the actual hearing?**
9. **What is another function of the ear, besides hearing?**

CHAPTER 47

The Frog

You probably wonder why we have a chapter on the frog in this part of the book. After all, we studied the amphibians in Chapter 34, and in this unit we have been studying the human body. But remember our reasons for studying the human body. We wanted to study the vertebrate body systems. We used man as our example. Any vertebrate would do, and man is the most important vertebrate to us. However, there is one drawback when we use man. We cannot do many experiments on him in class. We certainly cannot dissect him to see his internal organs! This is where the frog comes in. It will be our substitute. A frog has the same organs and systems that man has.

The living frog. We can begin by looking at a living frog. Get one if you can and examine it in class. If you do not have a specimen look at the one in Fig. 47-1. Notice its moist skin. This, of course, is a disadvantage to a land animal. The frog is in danger of drying up if it must stay in dry air too long. However, the moist skin serves a useful function in a frog. Oxygen from the air dissolves in this moisture and becomes absorbed. Blood vessels in the skin carry it to all parts of the body. The skin, then, is a sort of lung for the frog.

We absorb all of our oxygen entirely through the lungs. Our skin with its outer layer of dry dead cells cannot take in oxygen. The frog's lungs are simple sacs. They do not have branching air tubes like ours. They cannot absorb all of the oxygen needed by the frog.

The lining of the frog's mouth also absorbs oxygen. Watch how the throat moves up and down. This moves air in and out of the mouth cavity. Meanwhile the rich supply of blood vessels in the mouth lining absorbs the oxygen. Suppose the frog draws air into the mouth and then closes the nostrils. The next up-stroke of the throat forces air into the lungs. The next down-stroke draws it out again, and the next up-stroke sends it out through the nostrils. To fill and empty its lungs, a frog must move its throat (really the floor of its mouth), down and up twice. The nostrils are open half the time and closed half the time.

Watch for this opening and closing of your frog's nostrils. Actually you may not see it very often. The frog can go for quite a while using just mouth and skin breathing. Do you suppose the frog fills its lungs before diving?

Fig. 47-1. Side view of a frog. (Perkins/Annan Photo Features)

Look at the frogs "arms" and legs. Notice that they are very similar to ours. They have the same general shape. They have the same joints bending in the same directions. How many "fingers" are there? Notice the thin skin between the toes of the hind legs. We say the frog has webbed feet. What function do webbed feet have? Put the frog in a tank of water and see how it swims.

Frogs jump instead of walking or running. Turn your frog loose on the floor. Then try to catch it again. Notice that each time you reach for the frog, it jumps. It does not move far but it is far enough. You generally miss the frog. No doubt the frog's natural enemies often miss a frog dinner in the same way.

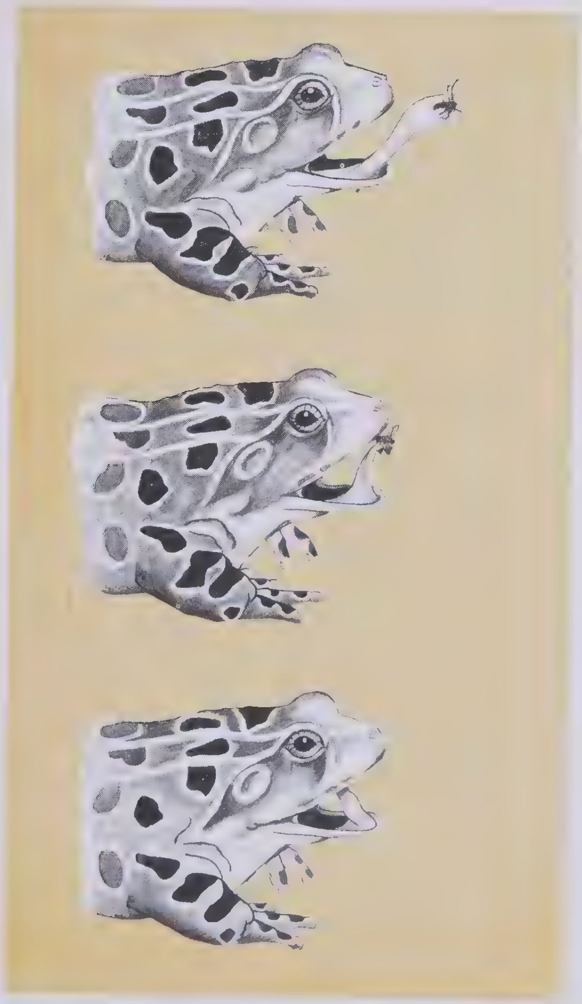
The frog uses its eyes in escaping enemies. How much does it see with them? Does it pay any attention to movements across the room? Usually not, but a frog responds very quickly to a movement nearby. Is it near-sighted? We shall see when we do our dissection.

If a frog is sitting quietly in its cage you can test its reaction to food. Ordinarily frogs eat live insects. You can make an imitation live insect by putting a bit of meat on the end of a fine wire. Move it in front of the frog like a fly. See how the frog jumps to grab the meat. Hold the wire so it will not

stick the frog in the mouth when it does this. Watch how the tongue is used to draw the "insect" into the mouth. See how nicely the tongue is arranged for doing this job. It is attached at the front of the mouth. It can flip outward and back again very quickly (Fig. 47-2).

Now we have learned something about a frog's behavior. It sits quietly most of the time. It pays no attention to movements at a distance. It jumps away from large moving objects near by (a hand, for instance). It jumps toward small moving objects (insects) and eats them. Touch the top of the frog's eyelid. See how the whole eyeball closes down into the skull for protection. The alligator and hippopotamus also have bulging eyes. Can you see any advantage to a water animal in having eyes that stick out in this way?

Fig. 47-2. A frog catching an insect.



Just back of each eye is a round disc. This is an eardrum. A frog's eardrums are not inside the head as ours are. We do not know how well the frog hears. It certainly hears many sounds, including its own mating call (Chapter 9). However, a frog's cochlea is much shorter and simpler than ours. This makes us believe that a frog cannot hear the differences between various kinds of sounds as well as we can.

Notice the coloring of your frog. Different species have different patterns, but black, green, and grey are usually the main colors. Would your frog be easy to see if it were sitting still in grass or pond weeds? Would its natural enemies see the frog? Would insects notice the frog before they flew too close?

The mouth. Now it is time to look inside the frog. We will start with the mouth. For this you may use a freshly killed frog or a preserved one. Schools buy preserved frogs from scientific supply companies. These frogs have been preserved in a formaldehyde solution. Wash the frog under a water tap before you begin this study. The formaldehyde kills all bacteria, so the frog cannot decay. Do not worry about handling these preserved frogs. After all, they are much cleaner than you are! You are covered with germs. There are no living germs on a pre-

served frog. Do not splash formaldehyde in your eye. It will sting. If this should happen, wash your eye with cold water.

If you start with live frogs, the simplest way to kill them is with chloroform. Soak a wad of cotton in the chloroform and place it in the bottom of a jar. Put the frogs in the jar and close it. Leave them there for several minutes after they quit moving. After this treatment the frogs are dead. Their hearts may go on beating for some time yet. You will see this heartbeat when you do your dissection. Probably your teacher will have killed the frogs just before you got to class.

Take a dead frog and clip through the jaw bone as far back as possible. Then pull the mouth wide open. In fresh frogs no clipping is necessary. See how really large a frog's mouth is. In man the mouth and throat and nasal passages are separate cavities. In a frog there is just one large cavity —the mouth (Fig. 47-3). The nostrils open through the roof of the mouth near the front. Nerve endings for the sense of smell are upon the walls of the nostrils (though of course you cannot see them). There is another pair of openings farther back in the roof of the mouth. They are located far to each side. One goes up to each middle ear. Remember that we also have openings from our throats to our middle ears. Do you remember what they do? If not turn back to Chapter 46.

Of course the largest opening out of the mouth (not counting the front one) is the one at the back. It leads to the stomach. We can call it the opening into the esophagus, but actually a frog hardly has an esophagus.

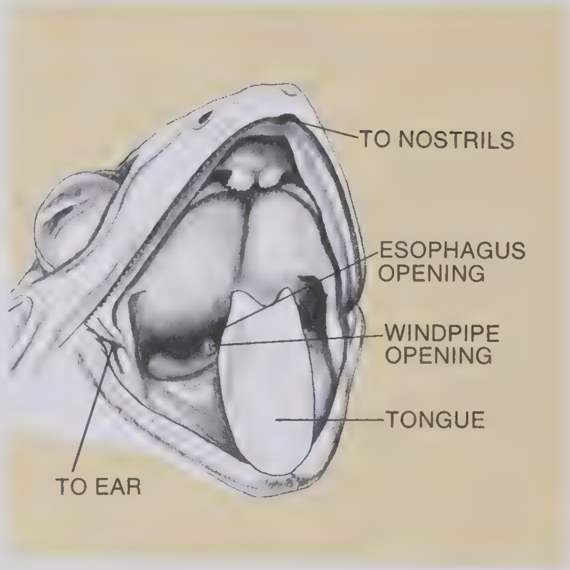


Fig. 47-3. The frog's mouth.

The mouth opens almost directly into the stomach. In front of the esophagus opening is a much smaller one leading into the windpipe. This opening is slot-shaped. It remains closed except when air is entering the lungs. Is there a similar part in the human body?

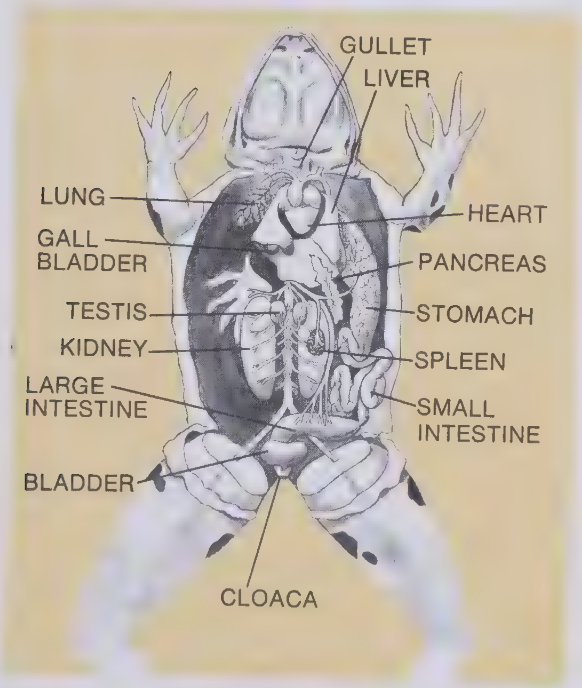
A frog's teeth have little importance. They are very small, and about all they can do is to give the frog a slightly better grip on its prey. There are no teeth in the lower jaw. Run your finger around the rim of the upper jaw. Notice that it feels rough. This roughness is due to a large number of tiny teeth. They form a line clear around the upper jaw. Notice the two rough bumps on the roof of the mouth. These also are groups of tiny teeth.

Internal organs. Now it is time to open up your frog. Use a pair of small scissors and trim off the skin from the entire lower surface of the body.

This will expose the white layer of muscles in the body wall. Trim this off also. Cut all the way around the outside and lift the body wall off like a lid. This will expose the internal organs. Be careful to lift upward with the scissors tips as you cut. This prevents damage to parts underneath. When you are even with the arms be sure to clip right through the bones which run across the chest. When the frog is opened up properly all parts are exposed, including the heart. If you are using a preserved frog wash the formaldehyde out of the body cavity.

Now take tweezers or a probe and move the internal organs around enough to see them all. Some lie over others. Do not cut anything loose. Study Figure 47-4 very carefully. It will be your guide. Try to name every part you find in the frog. Remember

Fig. 47-4. Internal organs of the frog.



that the drawing (Fig. 47-4) shows the parts pulled out of place somewhat so that most of them will show.

Notice that a frog has the same digestive organs that we have. Its stomach is very large and does more of the digesting than ours does. The intestines are shorter and simpler than ours. Frogs eat nothing but animal food. This is easier to digest than plant food. A frog does not need a long intestine.

The liver is the largest organ in a frog. Lift the right lobe of the liver and see the watery-looking gall bladder. The pancreas lies in the curve of the stomach. It is delicate and difficult to see. These organs all have somewhat different shapes from ours, but they have about the same functions (Chapter 39). Somewhere in the middle of the other organs is the small round spleen. Remember that it is a blood-processing organ (Chapter 40).

The heart is in the center just above the liver. It is simpler than ours (Chapter 40). It has two auricles, but only one ventricle. The blood from the lung and the body circulations are mixed somewhat in this ventricle. This does not matter in a frog, since it takes in oxygen through the skin and mouth lining as well as through the lungs. A frog is a cold-blooded animal and needs less oxygen than we do. All warm-blooded animals have four-chambered hearts.

The lungs are long and soft looking. They are in among the other organs. Look for them under the liver on each side. As we have said, they are much simpler than ours. Take a medicine dropper and fill a lung with water to see how it can expand. Open it up. See for yourself that it has no branch-

ing set of air tubes like ours. But it does have bubble-like air sacs all around the outside wall.

The reproductive and excretory organs are down under all of the others. Move the other organs out of the way so you can see them. Study Figures 47-4 and 47-5 and try to identify the parts. The kidneys are long dark-red organs lying against the back body wall. Their two ducts enter the large intestine close to the opening into the bladder. These kidneys have the same general functions as ours (Chapter 42). At the upper end of each kidney is a cluster of yellowish finger-shaped objects. These are the fat bodies. They contain stored energy in the form of fat.

If your frog is a male you will see a small white testis lying on each kidney. The testes connect with the small sperm ducts. Remember that testes produce sperms (Chapter 9). If your frog is a female, it will have ovaries in this same position on the kidneys. If they are full of eggs they will be very large. In fact they will be larger than all the other organs put together. You will have to dig them out of the way before you can see very much else. When they are not producing eggs the ovaries are small and watery-looking, like crumpled cellophane. The oviducts carry eggs to the lower end of the large intestine. The oviducts are nearly white and very much twisted and coiled. During egg production they are quite large and take up a good deal of room. At other times they shrink down to a much smaller size. In your class you may have frogs in several stages. It all depends on what time of year they were caught and preserved.

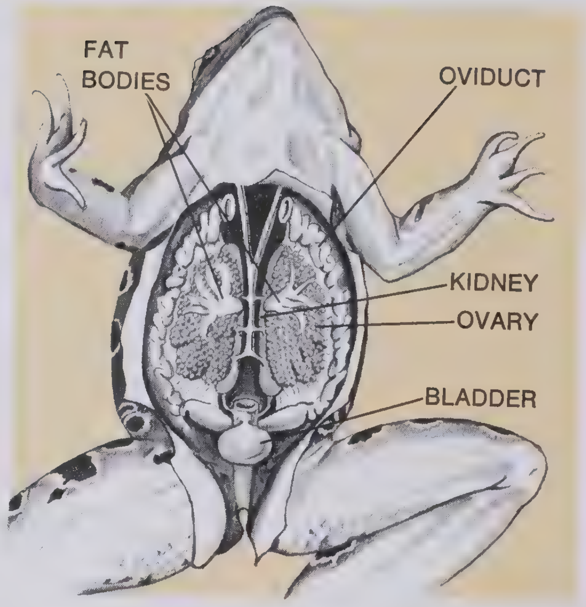


Fig. 47-5. Female reproductive organs of the frog.

The nervous system. Now turn your frog with its back upward. Skin the back and then try to expose the brain and spinal cord. You will have to work very carefully, for these nerve tissues are soft and easily damaged. One way is to shave the bone off with a knife. Another way is to slip the point of a tweezer under the bone and lift upward. This tears the bone off the nerve tissue. The brain starts about even with the front of the eyes and reaches to the back of the skull. The spinal cord runs from the back of the skull to the beginning of the hips. The cord is covered by muscle and the bony arches of the vertebrae (Chapters 43 and 45). The brain is covered by the top of the skull. Figure 47-6 shows the brain and spinal cord. Try to find the parts of your frog's brain.

Remember that the cerebrum is the biggest part of our brain. It does the thinking. How much thinking do you think a frog could do? The drawing

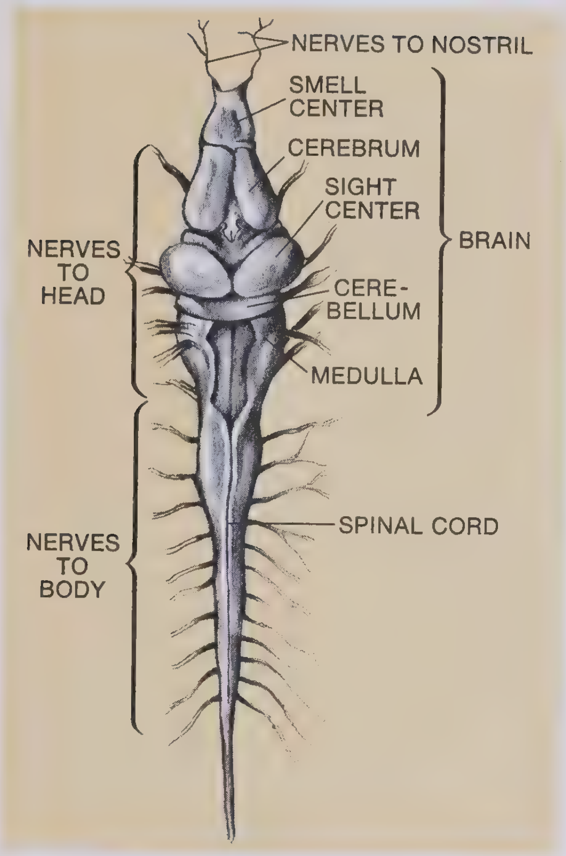


Fig. 47-6. The frog's brain and spinal cord. You can also see the beginnings of the main nerves.

shows nerves leading from the spinal cord to various body parts. If you look under the kidneys of your frog you can see some of these nerves. They look like little white lines. These are the nerves leading from the spinal cord down into the legs.

The eye. The frog's eye works much like the human eye. It has a cornea, an iris, a lens, and a retina. (Chapter 46). Remember that our lens changes its shape to change the focus of the eye. This gives us the ability to see both near and far objects. Can the frog's eye do this also? Cut open the frog's eyeball and remove the lens. You will find that it is clear and hard. It is almost a sphere. This very round shape would make it good for focusing on objects nearby. But it is much too hard to change its shape. Obviously it could not be made to focus on distant objects. No wonder our frog acted so nearsighted! Would farsighted vision be of much use to a frog? Remember where a frog sits, down among the grass and weeds. For its purposes nearsighted eyes are best.

The legs and bones. Now peel the skin off of the legs. Examine the muscles. They are very much like the ones in your leg (Chapter 43). Try pulling different muscles and see which way they pull the leg. See how each muscle tapers off into a tendon.

Next cut the muscles off the leg and expose the bones. See how they have tough ligaments binding them together at the joints. If you are careful you can scrape all of the flesh off a frog skeleton and glue it to a sheet of cardboard. This can make an interesting souvenir of your frog study. Of course you would need an extra frog for this. Your dissection has destroyed parts of the skeleton.

Notice that the frog has no ribs. It has no diaphragm either. Obviously it cannot breathe in the same way that we do (see Chapter 41).

The frog skeleton, however, serves about the same purpose as our own. It gives protection for delicate parts such as the brain and the spinal cord. It also gives the body its form. It is the structure to which many of the muscles are attached. The skeleton and the muscles work together to produce movements such as jumping or swimming.

CHECK YOUR FACTS

1. What responses does a frog make to its environment? How do its sense organs help in making responses?
2. How does a frog escape from its enemies?
3. How does a frog take in food?
4. Name all of the organs in the frog that are also present in man. Do they have the same functions?
5. What evidence do you have that frogs are nearsighted?
6. In what ways is man more highly developed than a frog?

CHAPTER 48

Disease

One of the human problems related to biology is that of keeping well. Disease prevents the body from working normally. It is important to all of us that we understand disease so that we can protect ourselves from it. There are two general types of diseases. There are those that are caused by parasites which enter the body and harm it in some way. Many of these are ***germ diseases.*** There are also diseases that are not caused by parasites. Some part of the body simply fails to function as it should. Such diseases are called ***functional diseases.*** Diabetes, which you studied in Chapter 44 is a functional disease.

The kinds of parasites that cause diseases. There are several kinds of parasites that cause diseases. They include forms from the following groups.

1. *Bacteria.* As you already know, bacteria are tiny one-celled protists (Chapter 19). Most of them are harmless, but some enter the body and cause diseases. They may attack and destroy body tissues. This happens in tuberculosis. In other cases the bacteria give off poisons. These poisons spread through the body in the blood stream, making the person sick. Diphtheria, scarlet fever, tuberculosis, most pneumonias, and many other diseases are caused by bacteria.

2. *Viruses.* You have read about viruses in Chapter 20. Remember that they are not cells, but when they are inside living cells they can reproduce themselves. Some diseases caused by viruses are smallpox, chicken pox, rabies, influenza, colds, mumps, polio, measles, and yellow fever.

3. *Rickettsias* (rik-*et*-see-ahs). Rickettsias are smaller than bacteria but are like bacteria in some ways. They carry on more of the chemical activities of protoplasm than a virus can, but not all of them. Rickettsias, like viruses, can multiply only in the cells of a host.

Spotted fever, typhus fever, and Q fever are some diseases caused by rickettsias.

4. *Protozoa.* Protozoa do not cause as many diseases as the bacteria and the viruses, but they do cause some very troublesome ones. These include malaria, African sleeping sickness, amebic dysentery, and several others.

5. *Fungi.* Certain yeasts attack the lungs and other tissues. Fungi produce athlete's foot, other types of ringworm, and jungle rot. The ears and lungs may also be attacked by moldlike fungi.

6. *Worms.* As you already know, the flatworm and roundworm phyla include many parasites. Chapter 28 describes four of the common types.

Some diseases are spread in water or food. In general, germs must move quickly from one host to the next because they cannot last very long outside the body. But there are exceptions. For instance, the bacteria that cause typhoid fever can live outside the body for months. Typhoid fever is a disease of the intestines, and the bacteria are present in the feces of a person who has the disease. If sewage is not properly disposed of, some of these germs may enter the water of wells, lakes, or streams. Anyone drinking such water may get typhoid. Swimming in polluted water or eating raw mollusks that grew in this water can also spread disease. Cholera and dysentery are two other diseases that are spread in water.

Food as well as water can be a carrier of disease germs. The same forms of disease that are carried in water may also be present in foods. Vegetables grown on ground polluted by sewage often carry parasites such as *Ascaris*, and the germs of cholera, dysentery, and typhoid. This is most common in countries where human sewage is left on the surface of the ground. In the far East it is used as fertilizer on the fields.

Bacteria may actually live and multiply in food. Milk, for instance, is such a good food that many kinds of germs can grow in it. Custards, which are made with milk, also serve as food for bacteria. Such foods must be produced under clean conditions to keep germs out. Refrigeration prevents

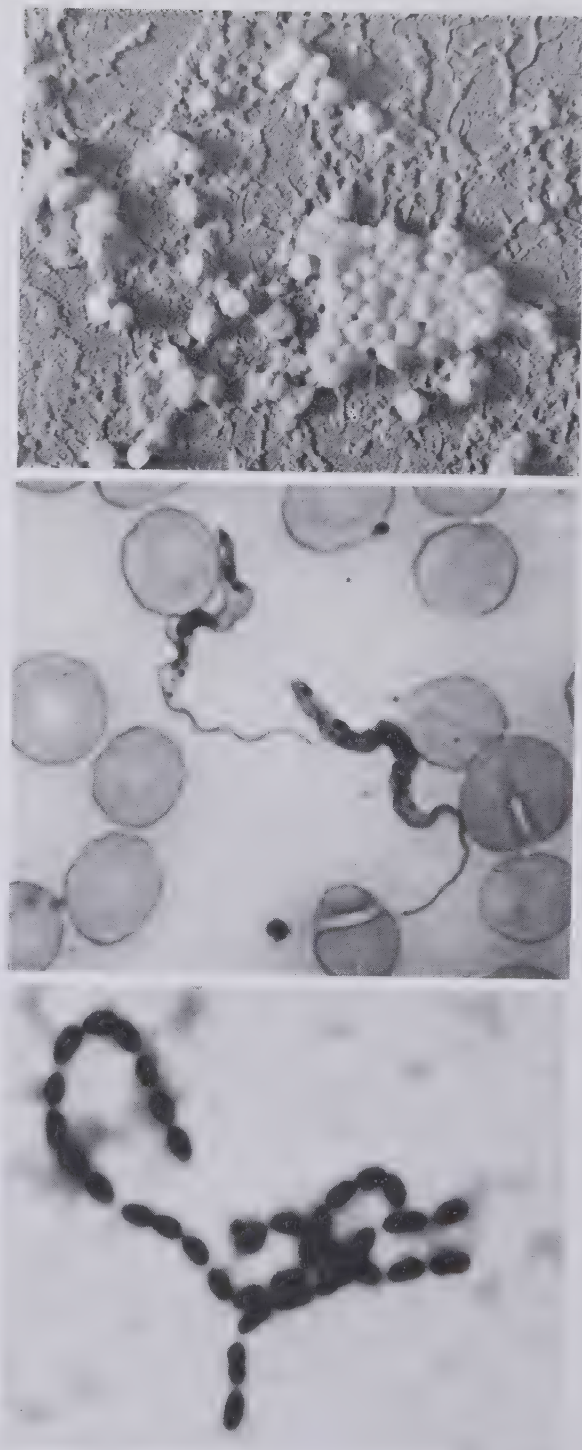


Fig. 48-1. Some agents that cause diseases. Influenza virus, Type B; the protozoan which causes African sleeping sickness; the bacteria which cause pneumonia. (Lederle Laboratories; Eric V. Grave; Lederle Laboratories)

the germs from growing rapidly if the foods are kept cold enough.

Some diseases are spread by arthropods. Some germs are carried by bloodsucking arthropod parasites. The parasite takes in the germ when it sucks the blood of a sick person. Later, when it bites another person the germ is passed on to him. Malaria and yellow fever are carried in this way by mosquitoes. African sleeping sickness is carried by the tsetse *(set-*see*)* fly. Typhus fever is spread by lice, ticks, mites, and fleas, and plague is spread by rat fleas.

Some insects spread germs without biting anyone. The common housefly is an example. Flies breed in damp manure. The larvae use the manure as food. When these larvae become adults, they fly from the manure piles into people's houses and walk on the food. The dangerous germs on their bodies are transferred to the food. Typhoid and dysentery germs are carried on the bodies of these flies. It is believed that cockroaches carry germs in a similar way. They hide in sewers, drains, and behind baseboards during the day. At night they come out and feed on human food. The bacteria which they tracked out of the sewers are left on the food for people to eat the next day.

Wound infection. Some types of germs enter the body through breaks in the skin and multiply in the tissue around the wound. These wound infections can be very dangerous. Deep, narrow wounds are especially bad. They are difficult to clean, and air does not go down into them. Pus-forming bacteria, streptococcus bacteria, and lockjaw bacteria *(tetanus)* can live in such wounds. All of these bacteria are very dangerous.

Airborne infection. The germs of many diseases are present in the saliva of the sick person at some time during the illness. These diseases spread through the air. Any time you talk, cough, or sneeze, tiny drops of saliva are sprayed into the air. The germs in

Fig. 48-2. Arthropods may also carry disease parasites. The tick (right) carries Rocky Mountain spotted fever germs, while the *Anopheles* mosquito (left) carries the germs of malaria (N. E. Beck, Jr./National Audubon Society; Russ Kinne Photo Researchers)

these drops may live long enough to be breathed in by another person. All of the common respiratory diseases are spread in this way—diseases such as colds, influenza, and tuberculosis. This spreading of a disease by means of small drops of saliva is often called *droplet infection.*

It is not possible to avoid these airborne germs. Any time people meet and talk they trade germs. Every day at school you take in cold germs, but you actually catch cold only once in a while. Most of the time you have the natural resistance to destroy the germs before they can grow in you. Of course the more numerous the germs are, the more difficult it is to resist them.

The body's defenses against disease. The body is protected in many ways against infection by germs. You already know about some of them. The skin is a barrier against germs. As long as it remains unbroken, most germs are kept out. The lining of the mouth, throat, and intestines are also fairly good barriers against germs. The acid in the stomach kills some germs. There are always harmless bacteria living in the intestine. These compete with any dangerous germs which may enter the intestine, and sometimes destroy them. You will remember how some of the white blood cells destroy germs that manage to enter the body tissue. Several other kinds of cells are able to destroy germs too. Some of these cells that can destroy germs are in the liver.

The body produces several kinds of chemicals which fight germs. Some kill viruses. Some kill bacteria. Some destroy the poisons produced by bacteria. Germ-fighting chemicals are found in the blood, lymph, tears, saliva, and in the body cells themselves. ***Antibodies*** make up one of the groups of germ-fighting chemicals. Each antibody fights one particular type of germ or germ poison. For instance, the antibody that kills smallpox virus has no effect upon mumps or chicken pox viruses. It will only work against smallpox.

Our bodies cannot produce antibodies unless the germ is present in the body. When germs enter the blood, antibodies begin to be produced in the lymph nodes. This often takes several days. During that time the white blood cells may not be able to keep all of the germs from growing and reproducing, so the person becomes sick. If the germs grow and reproduce too rapidly, he may die. But the antibodies usually get into production soon enough to save him. Now antibodies and white blood cells are able to destroy all the germs, and the person becomes well.

After an illness, the antibodies may continue to exist in the blood for some time. During this time the person will be *immune* to the disease, even if the germs are present. This immunity lasts only a short time for some diseases, such as the common cold. In other cases it may last for years or even for life. Each time the germ enters the body more of the antibody is made. This strengthens the immunity.

Heredity has an important influence upon disease resistance. Some people seem to be naturally immune to scarlet fever. Others get it as a mild disease. Still others are made very sick by the scarlet fever virus. These dif-

Fig. 48-3. Why would such diseases as cholera and typhoid fever be common in an environment like this, where people get their drinking water from the river? (Magnum for World Bank)

ferences seem to be inherited. Whole populations may differ in disease resistance. Smallpox, for instance, was a serious disease for Europeans who settled in America. It was an even worse disease for the Indians. Whole tribes were wiped out. The Jewish people seem to have more than average resistance to tuberculosis. Eskimoes are unusually sensitive to it. Can you explain how natural selection might account for such differences in populations?

Doctors can make you immune to some diseases. A doctor can make you immune to certain diseases by using something that causes the body to produce the right kind of antibodies. In *smallpox vaccination*, the virus of a similar disease called cowpox is scratched into the skin. This cowpox virus is not able to make a person really sick. It just forms a sore in the skin at that one place. The body forms an antibody to kill the cowpox virus. This same antibody makes the person immune to smallpox. It does this because the two viruses are so much alike. The same antibody will kill both of them.

Smallpox vaccination was discovered by an Englishman named Edward Jenner. He noticed that people who worked with cows did not get smallpox. He reasoned that the mild illness called cowpox, which they got from the cows, made them immune to smallpox. Just as he had thought, when he gave people cases of cowpox on purpose, they became immune to smallpox.

A substance, such as the one Jenner used is called a ***vaccine*** (*vak*-seen). Other vaccines are made by weakening or killing the germ with chemicals. A mutated form of the germ is often used. In still other vaccines, a weakened form of the germ's poison is used. Some of these treatments immunize for only a short time. Some are good for several years or for life.

Today, doctors immunize babies against six diseases during their first year. These are tetanus, whooping cough, measles, diptheria, polio, and smallpox. The doctor tells the parent when the children should come in again for "booster shots." These prevent the immunity from becoming too weak.

Besides the immunizations just mentioned, a person should have others if he is going to travel in countries where sanitary conditions are bad. What the person needs depends on where he is going. He is likely to need the typhoid vaccine. He may also need protection against cholera, typhus fever, and plague. Before traveling in the American or African tropics, yellow fever shots should be taken.

Fig. 48-4. How does vaccination make us immune to disease? (Lederle Laboratories)

You must always remember that being immune to one disease does not make you immune to others. For instance, being immune to smallpox does not protect you against polio.

Preventing the waterborne diseases. In many cases, sanitation is a very practical way of preventing disease. For instance, the typhoid shots are only good for a limited time. We seldom use them here, yet typhoid has become a rare disease in this part of the world. We have brought this about by preventing the spread of the germ.

The best way to prevent the spread of disease germs that live in water is to provide a pure water supply. Cities do this in several ways. Small cities often use well water. Some cities run huge pipes up into the mountains to bring in clean water from mountain streams. More often a city must depend upon a nearby river for its water supply. The river water is often polluted. This dirty water must be purified before it can be used.

A complete job of water purification includes the following steps:

1. *Settling.* River water is allowed to lie quietly in large tanks, bigger than swimming pools. This allows the mud to settle to the bottom.

2. *Chemical treatment.* Next, the water goes to other tanks, where chemicals are added. These form sticky flakes which settle to the bottom and take fine mud particles with them.

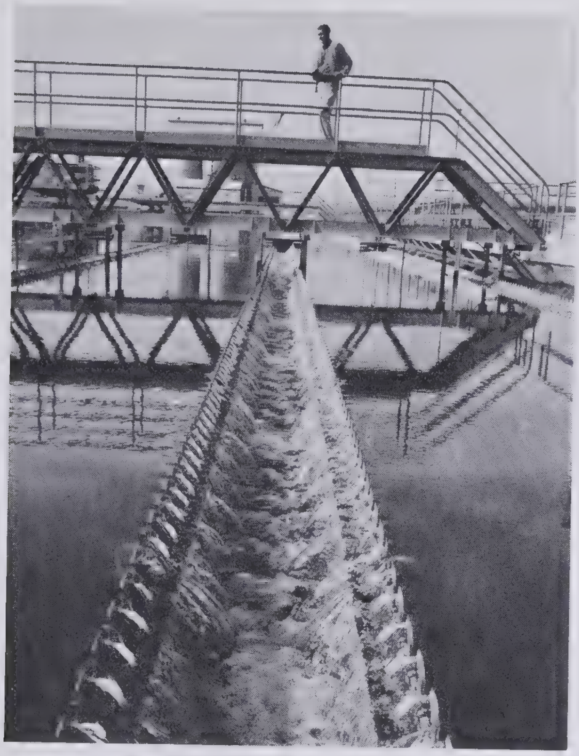


Fig. 48-5. A water purification plant. How do our cities make their water supplies safe for drinking? (United Press International Photo)

3. *Filtration.* The water, which now looks clear, is allowed to soak down through layers of clean sand and gravel. These layers are several feet thick. They act like a huge sieve which filters out any solid particles that may be left in the water. Most germs are also filtered out.

4. *Chlorination.* A small amount of liquid chlorine may be mixed with the water. This is an element that kills any germs that have not been filtered out.

5. *Aeration (air-ay-shun).* Sometimes the water is sprayed into the air by many nozzles that look like lawn sprinklers. This aeration process is used mainly to improve the taste of the water by dissolving air in it. Oxygen from the air also may kill some types of germs.

Country water supply. Well water is the best supply for country homes. A well is simply a hole which goes down into the ground water, below the water table (Chapter 15). Water flows into the well from the surrounding soil and fills it up to the level of the water table. This water can be pumped out with a hand pump, or it can be forced by an electric pump through pipes leading to the faucets in the house.

Ground water is usually safe to drink because germs were filtered out as it soaked down through the soil. However, bad well construction may let in surface water. Such water has not been filtered through the soil, so it carries germs into the well.

Today, most wells are made by drilling, or driving a pipe down into the ground. This pipe is called the well casing. At its lower end is a fine metal screen which lets in water but keeps sand out. Surface water cannot enter such a well through the solid walls of the casing. A rubber seal closes the top end of the casing around the smaller pipe which leads from the pump down into the well.

Sewage disposal. Many cities still dump their sewage into lakes or rivers. They take in their drinking water upstream from the town and dump their sewage downstream. They let the next town down the river worry about stream pollution. But some other cities now have modern sewage disposal plants. Since many of the most dangerous water-borne germs come from sewage, it is im-

portant to keep it out of the water supply.

There are many types of sewage disposal systems, but they are all based on the same idea. They allow decay bacteria to break down the sewage and change it into harmless materials. Very little solid material is left. What little there is can be dried and burned, or it can be made into a commercial fertilizer and sold to farmers. The liquid part of the sewage becomes purified and can safely be sent into streams.

However, there is a problem here that we have only come to realize recently. There are dissolved mineral salts in the clean water leaving a sewage plant. They do not carry disease, but they do upset the living communities in the water. Some kinds of algae use these minerals and grow very rapidly, completely changing the food chains. Clear-water fish like lake trout and walleyes disappear. Less desirable fish take their place.

Country sewage disposal. The old-fashioned outdoor toilet can be safe from a health point of view. It allows the wastes to decay in a pit in the ground. But the pit and the building must be sealed so that flies and rats cannot enter. They would carry germs to nearby houses.

A better method is to use a *septic tank* with a drain field. A septic tank is simply a large underground tank. The sewer pipe from the house empties into it. Decay bacteria rot the sewage materials in the tank. The outlet pipe from the septic tank leads into lines of drain tile which are laid about 20 inches underground. This is the drain field. It has loose, open joints between the sections of tile

Fig. 48-6. A modern sewage disposal plant. What has this to do with public health? (Dorr-Oliver, Incorporated)

pipe. The liquids soak into the soil through these joints.

In this set-up, two kinds of bacteria work on the sewage. Bacteria which do not use air carry on decay in the deep water of the tank. Those that use oxygen work on whatever is left when it flows into the drain field. Any germs that may be left are filtered out as the water soaks down through the soil. The water is safe by the time it enters the water table.

All of these methods that use bacteria are simply imitations of what has always happened in nature. Any left over animal remains decay. Any water and minerals that they contain are returned to the soil.

Protection of food. As you learned earlier in this chapter, food can carry disease germs. One of the important jobs of public health departments is to see that this does not happen. In most communities milk cannot be sold to the public unless it has been produced in clean barns and handled in a clean manner in milk houses and dairies. Before it is put into bottles it must be ***pasteurized.***

In one pasteurization process the milk is heated, but not boiled, and then it is suddenly chilled. This kills any dangerous germs the milk might contain. It also kills many of the harmless bacteria that turn milk sour. Pasteurized milk is not only safer to drink, but it also keeps longer than unpasteurized milk. The process has little effect upon flavor or food value.

Public eating places as well as dairies are inspected by health departments. They see that restaurant owners obey the laws that require cleanliness in preparing food and washing dishes.

Insect control. As you know, several diseases are carried by insects. Different kinds of insects have different habits, so we must fight them in various ways.

Mosquitoes have been one of the biggest problems. Mosquito larvae, called "wrigglers," live in water. We can, of course, drain the ponds, lakes, and marshes where wrigglers live. But usually this is not practical or desirable. These wet lands often have value in flood control, recreation, or wildlife conservation. Draining wet lands near cities is sometimes done in special cases. Even the water in old tin cans and plugged eaves troughs can produce certain kinds of dangerous mosquitoes. Sometimes oil is spread on the surface of the water. This keeps the breathing tubes of the wrigglers from breaking through the surface. They get no oxygen and soon die.

It is also possible to poison the waters of ponds and pools. This is expensive, and it will kill useful forms of wildlife. The most successful attack on malaria (which is carried by mosquitoes) has been to spray poisons around buildings where people live. This kills the mosquitoes most likely to bite people. Of course, only "soft" poisons that break down quickly should be used. Each person should also protect his home with screens. People who work out of doors can use insect repellants on their skin to keep from being bitten.

Houseflies are killed by poisons, but poisons do not do the whole job. The breeding places of flies must also

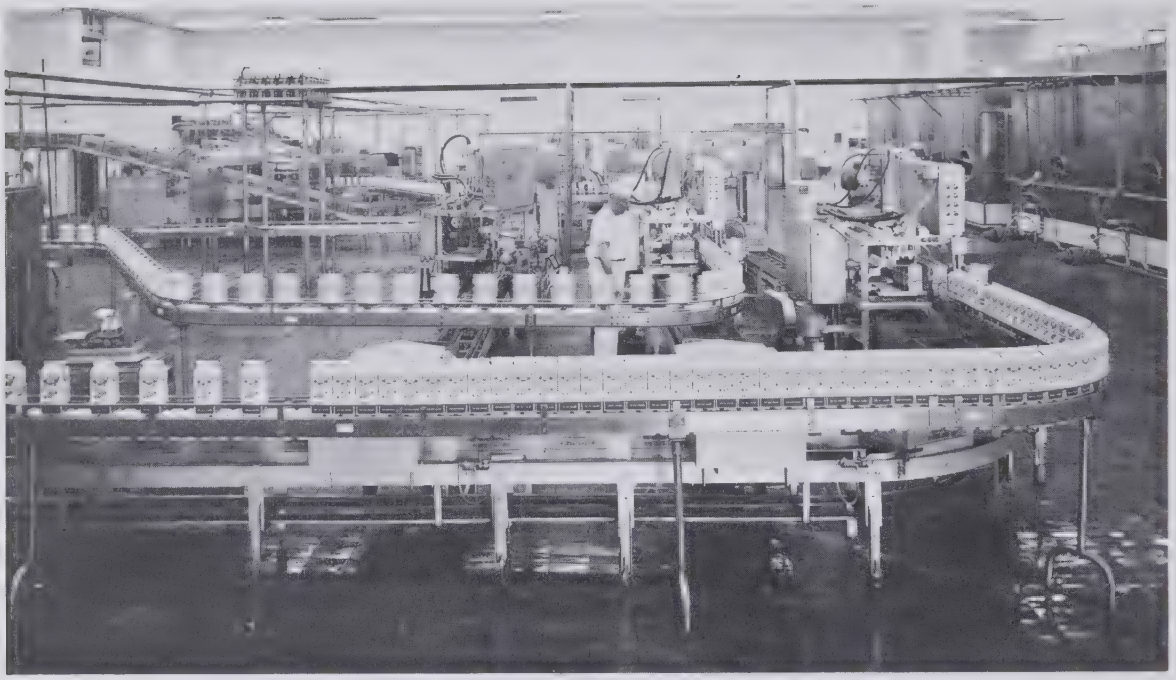


Fig. 48-7. How is our milk supply kept free from disease germs? (National Dairy Council)

be cleaned up. On farms, manure should be hauled out and spread on the fields frequently. Housefly maggots grow more in manure piles than in manure which has been spread out on the fields. In cities, garbage should be wrapped and placed in fly-tight containers. Then it can be disposed of by burning or burying.

Treating wound infections. Whenever you get a small cut you should clean the wound carefully with soap and water. This will remove the dirt which might contain dangerous germs. Then you should use a mild *antiseptic* (an-tuh-*sep*-tick) on the cut. The cut will heal best if it is left open to the air. It is often a good idea to cover the cut with a clean bandage. Then dirt is kept out of the wound.

Of course, any serious injuries should be treated by a doctor. He is the only one who can clean out a deep wound. He can use penicillin or other drugs to fight the germs of wound infection. He may also give an anti-tetanus shot. Tetanus germs cause a deadly disease that is sometimes called *lockjaw*. These germs live well in deep wounds. They are killed by too much contact with air.

Controlling airborne infections. As you have learned, it is not possible to avoid all airborne germs. Any person you meet may carry the virus of colds or influenza. But you can avoid having too many germs at any one time. Your body may be able to defend itself against a small number of germs. In fact, getting a few germs now and then may do some good. It may cause the body to produce more antibodies.

When too many germs enter the system at once, the body's natural defenses may be overwhelmed. There may not be enough white cells and antibodies to do the job, and the person becomes sick. Because of this it is good to avoid close contact with too many people when colds are common. Persons with colds should try not to cough or sneeze around other people.

Some old enemies. We have been so successful in our fight against many of the germ diseases that we almost forget about them. There is some danger in this. We are likely to get careless and let down our defenses. If we do, these same old killers can come back again to destroy us. A partial list of these diseases includes the following:

1. *Typhoid, dysentery, cholera.* These are water-borne diseases. They attack the intestine and they often kill. They are often present where the water supply is impure and sewage disposal is not sanitary. We have almost eliminated them here. If you travel to the less sanitary parts of the world get inoculated against typhoid and cholera, do not eat raw foods, and boil water before drinking it.

2. *Smallpox.* This disease has already been mentioned. Just about everyone got it in the past. It makes a person break out all over his body with foul smelling blisters, which leave scars when they heal. He is very sick. Often he dies. Vaccination has made smallpox a rare disease. Now and then, however, there are outbreaks of it. This is because people become careless and do not get vaccinated every three years.

3. *Plague.* You may have read about the "black death" in your history books. It has killed as many as half the people in a country in a single year. The disease is carried by rodents, especially rats. Fleas then carry the germ from rats to people. Modern, clean ways of living have made this disease much less common. Also, the brown rat has replaced the old roof rat, that more often carried the plague. However, the germ is still

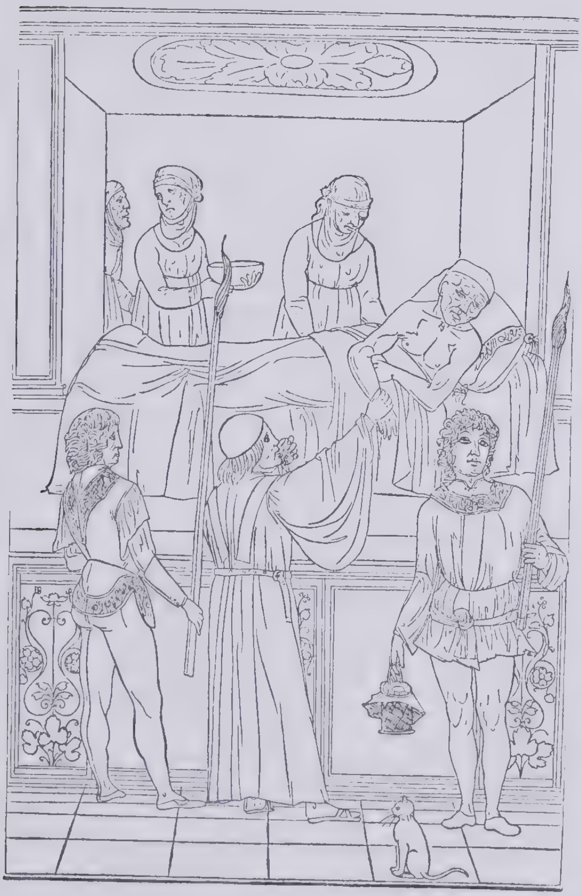


Fig. 48-8. This drawing pictures one of the great plagues of the Middle Ages. The "black death" killed so many people at once that they had no time for funerals. Bodies were picked up like so much garbage. Why does the plague not kill like this today? (The Granger Collection)

present in some parts of our land. A few hunters get plague from wild rodents each year. There is an inoculation you should get if you go to any Far Eastern country.

4. *Diphtheria.* Diphtheria germs grow in the throat, and can cause it to swell so it is almost shut. Poisons then spread throughout the body and may kill. Once many children died from this disease every year. If all parents had their children inoculated, as they should, there would be no diphtheria today. It is rare, but there are still a few cases each year.

5. *Tuberculosis* used to be a big killer. It is an air-borne disease which may attack any part of the body, but most often it settles in the lungs. This disease is still a major health problem. There are a good many cases, but not many deaths occur. A number of new drugs make it possible to treat people at home.

6. *Pneumonia* is a lung infection. It still kills many people, but much fewer than in the past. Antibiotics will usually save the person if he gets to the doctor. All the penicillin in the world will not help if it stays on a shelf at the doctor's office. If you ever get a fever, along with chest pains and cold symptoms, call the doctor. There is no time to lose.

7. *Malaria* has been the most common disease of man. This may be hard for you to realize if you live north of malaria country. In the warmer parts of the world, however, large numbers of people still have the disease. Some of them die. The germs of malaria are protists and they are carried by certain kinds of mosquitoes. As we have said, insecticides are helping to reduce the amount of malaria in

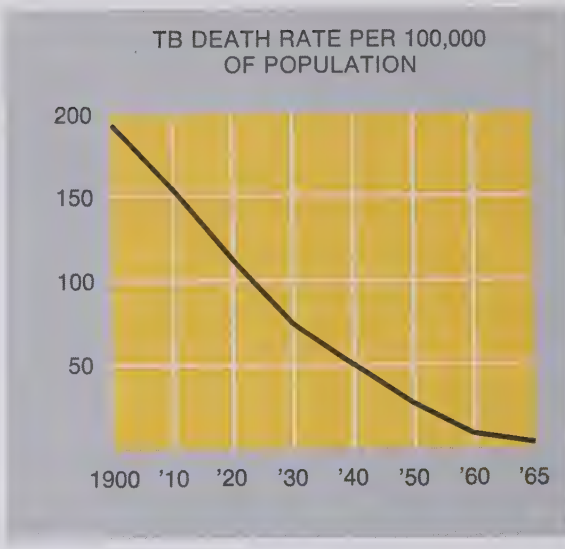


Fig. 48-9. These figures show that there has been a decline in the annual death rate due to tuberculosis.

the world, but it is still a problem. There is no vaccine, but there are drugs that can be taken daily to help a person resist the disease.

8. *Yellow fever.* We think of yellow fever as a tropical disease, but in the past it has caused trouble as far north as Philadelphia. It is carried by several species of mosquitos. Destroying the mosquitos prevents the disease. People of some tropical races have a considerable amount of natural resistance to yellow fever. Among northern races, two out of five who get yellow fever will die.

These samples of diseases are enough to show how important it is to be on our guard. These old enemies are still present in other parts of the world, and they will return here whenever we get careless.

Heredity and disease. As we have said, some people are naturally resistant to certain diseases. There is not much

practical use we can make of this fact as far as people are concerned. We have very little control over human heredity. But we can make good use of heredity in fighting the diseases of our farm crop plants.

Scientists are constantly trying to improve food plants. They cross many types and then carefully select the most promising offspring to use in making more crosses. The idea is to bring just the right genes together and to produce exactly the kind of plant that we need. Disease resistance is one trait that can be selected in such work. As a result of this built-in disease resistance we now produce many times as much sugar, rubber, wheat, oats, tomatoes, and many other farm products than we could otherwise.

Treatment of disease. So far, we have explained what disease is and how we prevent it. Sometimes prevention fails and we get sick. What can be done for the sick person?

If you do get sick it is a good idea to go to bed for a while. Resting in bed gives your body the best chance to fight back against the germs. Most serious germ diseases cause a person's body temperature to rise. This is ***fever.*** Each family should have a thermometer. Then when someone becomes sick they can see how much fever he has and report it to the doctor. This will give the doctor some idea whether he should come to see the patient, or whether the patient should come to his office.

Calling the doctor early in an illness is important. Many diseases are much easier to treat early than they are after they have become worse. Taking medicines at home without calling a doctor is not a good idea. You know very little about drugs and illness. You are very likely to take the wrong thing.

The doctor has the use of some excellent drugs. Penicillin, for instance, kills many kinds of bacteria, usually without hurting the person the bacteria are living in. You learned in Chapter 22 that it comes from a common green mold. The penicillin produced by the mold destroys bacteria which compete with the mold for food. From other molds we obtain antibiotic drugs such as streptomycin, terramycin, achromycin, chloromycetin, and several more. Some germ-killing medicines including several antibiotics are made chemically by the drug companies. The sulfa drugs are an example of this.

Treating functional diseases is a little different. There are no germs to fight. Many functional problems can be helped with surgery. An operation may not make a person as good as new, but it may make a normal life possible for someone who would otherwise be an invalid. Surgery often helps people with such widely different problems as heart defects, common rupture, ruptured discs in the backbone, cloudiness in the cornea or in the lens of the eye, club feet, and cleft palate.

Other functional diseases are helped by using drugs. You have read about the use of insulin in treating diabetes. Other hormones are used in treating problems related to other glands, including the thyroid, pituitary, adrenal, and reproductive glands.

Arthritis is a functional disease that causes a great deal of discomfort and pain to many people as they get older.

So far no good treatment has been found. Research continues to look for an answer. Cancer is usually listed as a functional disease. In cancer, some of the person's own cells grow rapidly, out of control. They take up the food and space which should go to the normal body cells. A few kinds of cancer are now thought to be caused by viruses, but the other types are still a mystery.

The two most useful treatments for cancer are surgery and radiation. The surgeon attempts to remove all of the cancer cells before they can spread to other parts of the body. Radiation kills cancer cells even more quickly than it kills healthy cells. The idea is to use enough radiation to destroy all of the cancer without doing too much damage to other tissues. In any case, cancer needs to be treated early. Any unnatural swelling, bleeding, or pain should be reported to the doctor promptly.

General health rules. What are some good general rules to follow if we wish to stay healthy? First of all, remember that much of our good health depends upon community action. We must organize to prevent disease in the whole area. You have already seen how plumbers and engineers do work that saves thousands of lives. They give us safe water and clean living conditions. So we do not get many diseases that used to be real killers.

You can do a good deal to help yourself. Go to the doctor for regular check-ups, so he can help you stay well. Have him give you all the vaccines he recommends. Many of the old killers are rare today because people do this.

You can be clean in your habits. Keep yourself, your clothing, your food, and your house clean. Eat the right foods. You cannot develop a healthy body on just a few snacks of soda pop and potato chips. Get enough sleep. This means enough so that you really feel rested and ready to get up in the morning. The average person needs about eight hours. Get some exercise every day. Develop a cheerful, healthy set of attitudes toward life.

ACTIVITY

Controlling the spread of disease. As you know, some diseases are spread through careless disposal of sewage, or by drinking contaminated water. Make a report on how your community disposes of its sewage and how it obtains its drinking water. There may be pamphlets available that give this information. Write or call your water and sewage departments to find out. Perhaps your class can arrange a trip to the sewage disposal plant or to your water purification plant. Are you satisfied that your community is doing a good job? If not, how could it improve its sewage disposal methods? Its water purification methods? Are there any local problems of water pollution?

Reporting on diseases. Each member of the class should look up the facts about some disease and report his findings to the class. Find out the cause of the disease, how it spreads, how serious it is, and how

it can be prevented or cured. It may also be interesting to report on the lives of men who studied the disease. The list of diseases to report on could include colds, influenza, pneumonia, tuberculosis, smallpox, measles, mumps, whooping cough, tetanus, polio, yellow fever, malaria, typhus, plague, scarlet fever, German measles, leprosy, filaria worm, Guinea worm, nephritis, hepatitis, cholera, dysentery, typhoid, cancer, heart disease, and many others.

CHECK YOUR FACTS

1. **What are the two main types of disease?**
2. **What kinds of germs can cause disease?**
3. **List several ways in which disease germs are spread. Give examples.**
4. **How does the body defend itself against germs?**
5. **Why does having a disease often leave us immune?**
6. **How do vaccines make us immune?**
7. **How is river water made safe to use as a city water supply?**
8. **What is the best water supply in most country locations?**
9. **How can sewage be disposed of safely?**
10. **How can we make sure that foods do not contain disease germs?**
11. **What is our defense against airborne disease?**
12. **What are some serious diseases that killed many people in the past? How do we keep them from doing so today?**
13. **Why is it easier to fight germ diseases than functional ones?**
14. **What are some things you can do to keep from becoming sick?**
15. **What should you do if you are sick?**

CHAPTER 49

Alcohol, Narcotics, and Tobacco

Our health is influenced by many things. These include heredity, food, mental attitudes, and germs. In addition, there are some chemicals that can affect our health. People may take these chemicals in drinks such as wine and whisky. They may be inhaled in tobacco smoke. They may be taken in various ways by "dope" addicts. In this chapter we shall see what is known about the effects of such drugs upon our bodies.

Alcohol. You learned in Chapter 22 that alcohol is a substance produced by yeasts. It is present in such beverages as beer, wine, and whisky. When alcohol is taken into the human body it affects all the cells, especially the cells of the nervous system.

Alcohol in the body is broken down into harmless materials by enzymes of the liver, but the liver can handle only limited amounts at one time. If alcohol is taken in faster than it can be destroyed, the extra alcohol circulates in the blood, where the cells can absorb it. Alcohol is poisonous to the human body, and one can drink enough alcohol to be killed by it. If a killing dose is taken at one time, the person usually throws up, and this saves his life. This much alcohol is too irritating for the stomach to hold.

Effects of alcohol. The general, overall effect of alcohol upon the nervous system is to slow it down. Nerve impulses do not travel as easily or as quickly. One drink of wine is enough to slow down reaction time. ***Reaction time*** is the time it takes to respond to a stimulus. For instance, the average reaction time for stepping on the brake of a car when a green light changes to red is about one-half second. During that time the car continues to move at full speed. If the person has been drinking even a little he will not respond as quickly. The car will travel farther before stopping.

With a little more alcohol in the system another effect appears. The judgment centers in the cerebrum are put out of action. The person can no longer judge proper behavior, or perhaps even the difference between right or wrong. The lower, more primitive brain centers are left in full charge. What happens next depends upon his personality.

If the person who has had this much

to drink is someone who admires clever talk, he may try to be the life of the party. He may tell the same joke several times in the same evening, laughing more loudly each time. He raises his voice because he cannot hear himself. The sense of hearing is dulled by alcohol. A person who admires muscular ability may decide he can beat anyone, and he gets into fights. Sad people become even sadder. They weep into their drink while telling all of their troubles to anyone who will listen. Nearly everyone talks too much, telling things he would normally keep secret.

These changes in behavior represent the acting out of secret desires—desires that are usually kept under control by the person's better judgment. With judgment destroyed by alcohol, the person thinks he really is clever, or strong, or whatever else he wishes he were. He may do things which are actually wrong.

A person who commits a crime after drinking is probably one who already wanted to be a criminal. Normally, he fears being caught, but with judgment put to sleep, he goes ahead. The truly honest person does not wish to commit a crime, so he will not do it even when drunk.

The personalities of some people are not changed by drink. They are slowed down mentally, but that is all. These are people who are well adjusted emotionally. They are satisfied to be themselves, and they have few secret desires. These people generally do not care much for alcohol. After all, there is no particular fun in becoming stupefied.

As more alcohol reaches the brain,

Fig. 49-1. Even moderate drinking slows reaction time and reduces good judgment. Can you see why it is that in over half of our automobile accidents at least one driver has been drinking? (Wide World Photos)

the motor centers are greatly affected. Speech is blurred, and muscular movements are clumsy. The balance center in the cerebellum cannot do its work and the victim begins to stagger. If still more alcohol is taken, the drinker will be so stupefied that he goes to sleep. This is fortunate for him. If he had stayed awake to take still more, he would be dead.

Of course some people do manage to drink themselves to death, over a period of time. Years of heavy drinking ruins the whole body. Heavy drinkers do not eat normally, and as a result they get deficiency diseases. The final stages often include a form of insanity.

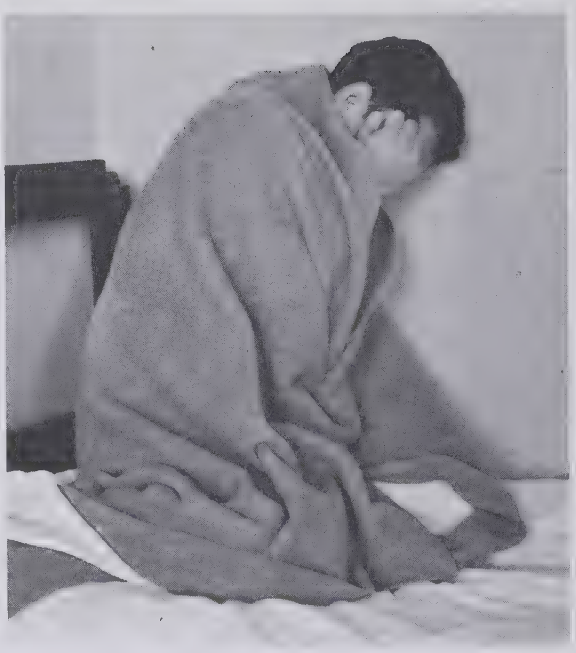


Fig. 49-2. A narcotic addict suffering from painful withdrawal symptoms after the drug has been taken away from him. (Wide World Photos)

What is alcoholism? Alcohol is not habit-forming for most people. They can drink or not as they choose. But it is habit-forming for about one person in 15. These people are called *alcoholics.* If there are 30 students in your class, then about two may be expected to become alcoholics if they start drinking. There is no way to tell ahead of time who these possible alcoholics are. Each person who drinks takes this chance.

An alcoholic feels he *must* drink. He drinks even when he knows it is ruining his life. There is some reason to believe that the body chemistry of the alcoholic is different from that of other people. His ability to use vitamin B may not be normal. In any case, he needs help.

Doctors, psychiatrists, ministers, and rescue missions have all helped alcoholics. The organization called Alcoholics Anonymous does good work. The alcoholic will never be really cured. That is, he will never be like normal people who can drink or not as they choose. With help, he *can* stop drinking. After that he must not drink *at all*, or his problems will start over again.

Habit-forming drugs. ***Drug addiction*** is a situation in which a person keeps taking some drug and comes to depend upon it mentally and physically. He feels that he cannot stop. He must take more. Usually the doses get bigger as time goes on. Drugs that do this to a person are called *habit forming.*

Some of these drugs are useful to the doctor. He uses them to relieve pain. The most useful one is *morphine (mor*-feen*). Cocaine* is also used in drugs that deaden feeling in one part of the body. Novocaine is a substitute used in the same way by dentists. It is safer than cocaine.

Morphine comes from opium, which is made from the juice of a poppy. Cocaine comes from the leaves of a shrub. Drugs of this general type are commonly called ***narcotics.*** They should never be taken except when prescribed by a doctor. The narcotic which addicts generally take is *heroin (hehr*-oh-in*).* It is not used in medicine.

Marijuana (mah-ri-*wha*-na) is a dangerous drug that is smoked in cigarettes called "reefers." Different people are affected by it in different ways. Some react by committing violent crimes. Some have committed suicide but most people just become dreamy. One of the bad things about marijuana is that if often leads people to use even more dangerous drugs. Having heard that marijuana has mild effects, they give it a try. The next thing they know they are using heroin.

The idea that marijuana is harmless is often heard these days. People who say this cannot really know what they are talking about. Chemists did not separate the active chemical from the plant material until recently. Truly scientific studies have only now been made. Before this no one really knew what the effects were. These recent studies show that the regular use of marijuana often leads to permanent mental or physical illness. Even users who do not develop the worst effects are harmed. While they sit back in the dreamy condition produced by the drug, life passes them by. They do not meet and solve their real problems.

Drug addiction is a trap. Anyone who begins to use a narcotic is trapped. When he first starts taking the drug he feels as if everything is all right. He does a great deal of day-dreaming. Soon he can think of little besides himself and when he will get his next shot. He becomes a poor worker and loses his job. As time goes on he becomes short-tempered and moody. His skin is pale and may develop a rash. He sweats heavily and becomes sloppy and dirty in his habits. He may even start to show signs of becoming insane.

If an addict fails to get his drug he suffers ***withdrawal symptoms.*** His body has become adjusted to the drug and will not work normally without it. A person suffering from withdrawal symptoms has painful muscle cramps. His arms and legs feel as if they are being torn from his body. He is sick at the stomach. He feels as if snakes are crawling under his skin. He has a severe headache. He cannot sleep or even sit still. He may die.

So he feels that he *must* get his drug, and the drug peddler is waiting. This "pusher" may have given the addict some free shots to get him started. But now that his victim is "hooked, the price goes up. It takes the average addict about 20 dollars a day to get his drug. This is a lot of money for someone who cannot even hold a job, and often the addict turns to crime to get it.

Druggists cannot sell drugs to addicts. The law forbids it. The drug peddler is a criminal who makes his money by tricking people into trying the drug a few times, "just to see what it is like." Perhaps he dares them to show that they are not afraid. The new addict soon finds that in trying to prove he was not "chicken" he has become a "sucker." He had thought

he could stop whenever he wanted to, but, of course, he cannot. The dope peddler charges prices two or three hundred times what they would be if the same drugs were sold by druggists on doctors' prescriptions. Twenty dollars worth of morphine brings about *four thousand* dollars on the illegal market.

Recently many new drugs have come into use. Technically they are not true narcotics, but like marijuana and the narcotics, they *do* affect the mind. People who cannot bring themselves to face reality like to escape into the dream world of drugs. These new drugs are *synthetics.* This means they are manufactured by chemists. They are not extracted from plants, like the older drugs.

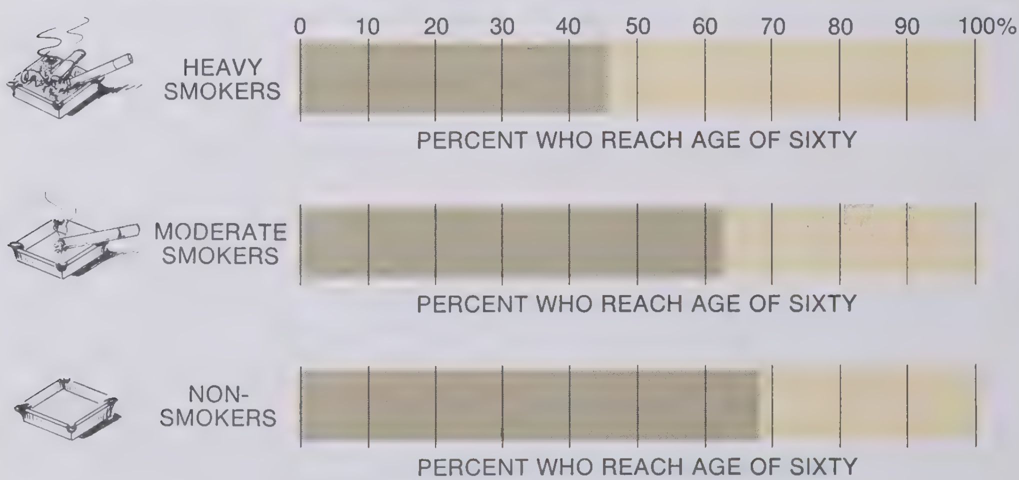
The best known of these new drugs is L S D. People who use it often become sloppy in appearance and neglect their education and their jobs. In the long run they are very likely to fail in finding a good way of life. There is often permanent mental damage. They end up seeking the help of psychiatrists to try to save what is left of their personalities.

Drug addicts can be helped. Most states and large cities have hospitals or clinics for treating them. The person who wants this help can ask his family doctor how to get it, or he can call almost any hospital or social agency in his area. They will tell him where to find help.

Tobacco can also injure the body. Tobacco, of course, does not ruin a person, the way narcotic drugs do, but it is a waste of money. It gives the smoker nothing he would have missed if he had never started. Some people are able to stop smoking, but most of those who start continue for the rest of their lives. Like the narcotics, it is habit forming.

In the past it was often thought that smoking was entirely harmless. In recent years there have been several studies made of the problem to find out just how the habit does affect

Fig. 49-3. What connection does this graph show between smoking and the length of life?



people. These studies have shown that heavy smoking shortens life in many cases. People who smoke two or more packs of cigarettes a day are considered heavy smokers. About 68 percent of nonsmokers reach the age of 60. Only about 45 percent of heavy smokers live that long.

Lung cancer is a serious disease that usually kills. Heavy smokers of cigarettes are about 25 times more likely to get lung cancer than nonsmokers are. Average smokers get it ten times as often as nonsmokers. In 1964 the Office of the Surgeon General of the United States issued a report on smoking stating that there is a definite relationship between cigarette smoking and serious lung and respiratory ailments.

Of course, many cigarette smokers may never get lung cancer, but they all have lung damage. The cilia lining the air passages of the lung gradually disappear. A layer of abnormal cells develops in their place. The lungs lose much of their ability to get rid of dust. We can say quite truthfully that the cigarette smoker has crippled lungs. If this damage were out where we could see it there might be a lot fewer smokers!

In many smokers the air sacs of the lung become enlarged and inefficient. The person must breathe harder to get enough blood pumped through the lungs. Smokers have more heart disease than nonsmokers. Cancer of the voice box is far more common in cigarette smokers than in other people. Such people must have their voice box removed. From then on they breathe through an opening in their neck. Lip cancer is most common among pipe smokers.

In general, cigarettes seem to do much more damage than pipes or cigars. This may be because most cigarette smokers inhale the smoke. Any kind of smoking, however, is likely to shorten life somewhat. Of course some smokers do live a long time. But no one can know who these lucky ones will be. The *average* smoker does not live as long as the *average* nonsmoker.

As you see, smoking is a habit that costs money and damages health. If you wish to stop smoking the best time to do it is before you start. It is easy to leave cigarettes alone if you never had had the habit. You will have more

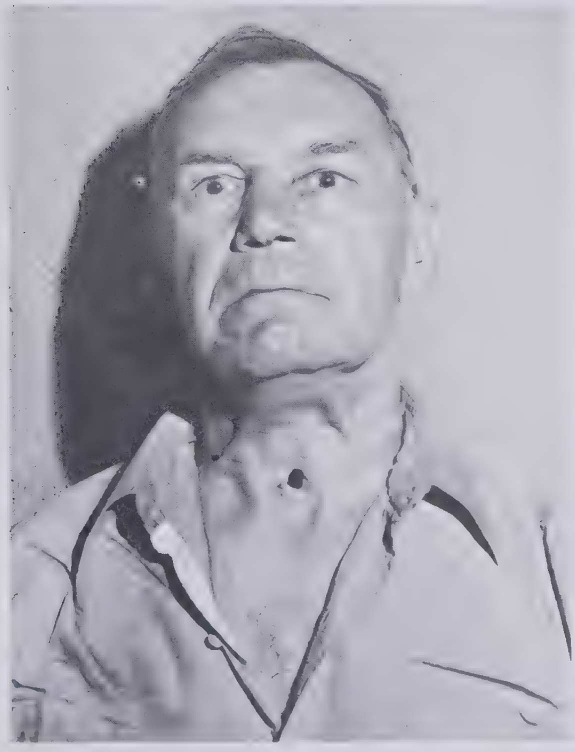


Fig. 49-4. This man has no voice box. It was removed to save him from cancer and he now must breathe entirely through the hole in his neck. Could he talk? Do you think he would advise you to smoke? (Speech Rehabilitation Institute)

trouble if you are already a smoker. The body develops a hunger for tobacco in somewhat the same way it does for narcotics. A person will miss his smoking most for the first month or two after he stops. It will help if he can arrange to be doing things he enjoys during this time—hobbies or a vacation trip, for instance. This will serve to keep his mind busy. He will not have as much time to think about how badly he wants to smoke. In this way a great many people have given up the smoking habit. Most of them do not start up again. After a time they are only too glad not to be bothered any more. Each person must make up his own mind whether or not he wants to belong to the "sucker club."

ACTIVITY

A study on smoking. Obtain a copy of the government report on smoking. It is called **Smoking and Health.** It is probably in your library, or it can be obtained from the Superintendent of Documents in Washington, D.C. for $1.25. What does it say about the effects of smoking upon health? What kind of investigations were made to discover these facts? Why do you think people start smoking? Why is it so difficult for them to stop?

CHECK YOUR FACTS

1. **How does alcohol affect reaction time?**
2. **Why do people act differently when they have been drinking?**
3. **What finally happens to alcohol in the body?**
4. **What is alcoholism? How does it affect the alcoholic?**
5. **What are narcotics? Do they have any good uses?**
6. **Why is it so hard for a drug addict to stop taking "dope?" In what way can he be helped?**
7. **How does smoking affect length of life?**
8. **What diseases are more common among smokers?**

UNIT 7 SUMMARY

Food provides energy. It also supplies materials for the growth and repair of cells. The number of Calories a person needs depends on sex, size, type of activity and the way a person's body functions. If one takes in more food than his body requires, fat is stored. The human body also needs certain minerals and vitamins.

The five classes of foods are the carbohydrates, fats, proteins, minerals, and vitamins. Lack of vitamins produces deficiency diseases. The diet should include vegetables and fruits, meat, whole grain breads and cereals, and milk or milk products.

Before any of these foods can be absorbed, they must be di-

gested. Foods that we eat are broken down into molecules that are soluble in water. Digestion depends on enzymes. In man, the digestive enzymes are in saliva, gastric juice, pancreatic juice, and intestinal juice. Food molecules are absorbed by blood and lymph vessels in the wall of the small intestine.

The basic blood fluid is plasma. In this plasma are large numbers of red blood cells and much smaller numbers of white blood cells. The red blood cells are the main carriers of oxygen. White blood cells destroy foreign matter, including some germs. The blood carries food molecules, water, and oxygen to the cells of the body. The more fluid part of the plasma escapes through the capillary walls and becomes tissue fluid. This tissue fluid bathes the cells. Some of the tissue fluid then enters the lymph vessels and becomes lymph. Lymph vessels return the lymph to the blood at two points just above the heart. The liver, kidneys, and spleen remove wastes, damaged cells, and foreign matter from the blood.

Air enters the body through the nasal passages of the mouth and goes through the throat, the voice box, the windpipe, and branching air tubes to the lung tissues. The lungs contain many small air sacs. Small, branching air tubes reach all of these air sacs. Capillaries in the walls of the air sacs get oxygen from the air, and get rid of carbon dioxide.

The skeleton gives the body its form. Many of its bones act as levers that make muscle movements more effective. The bones surround and protect some internal organs, such as the brain. The skeleton of a very young child is first formed as cartilage. As the child grows older, a good deal of the cartilage is replaced by bone. Bone and cartilage are made up of cells. But they also contain much nonliving material that has been deposited between their cells.

Many of the muscles of the body are attached to bones by tendons. Muscle contractions produce body movements. Muscle cells cannot push; they can only pull. ATP furnishes the energy they must have to do this work.

Ductless glands produce hormones which they discharge into the bloodstream. These hormones are the chemical messengers of the body. They control many body functions. When too much or too little of any hormone is produced, one or more body functions is soon out of balance.

The nervous system receives a great many stimuli at all times. Some come from inside the body; others come from without. Sensory nerve cells receive stimuli and send impulses to control centers. Motor nerve cells then carry impulses to the muscles and glands. The muscles and glands act to produce responses.

Some of man's responses are simple reflexes that are automatic.

Intelligent acts depend on the cerebrum which is the largest part of the brain. The cerebrum is the center for memory, for thinking, and for directing responses. The complex human responses are learned. Habits are response patterns that have been repeated so often that we no longer have to think about them.

The special senses include sight, hearing, smell, taste, touch, balance, pressure, heat, cold, pain, and muscular effort. They make us aware of changes inside and outside our bodies. Light rays reaching the retinas of the eyes cause nerve impulses to go along the optic nerves to the brain. Sound waves reaching the cochleas of the ears pass along the auditory nerves to the brain. The sense of balance depends on the semicircular canals in the inner ears.

Germ diseases are caused by bacteria, viruses, rickettsias, protozoa, and fungi. Some other diseases are caused by parasitic worms. We get certain germs from impure food and water. We get others through the bites of various arthropods. Many germs get into the body through wound infections and droplet infections.

Our bodies have natural defenses against germs, which include the skin, some of the white blood cells, and antibodies. The antibodies are chemicals that destroy germs or keep them from reproducing. They develop when the body is attacked by certain germs. Vaccines also cause the body to produce antibodies. These antibodies make the body immune to various diseases. You can be immune to one disease, but unprotected against another. Some immunities last a long time. Other immunities are only temporary.

Antibiotics and sulfa drugs have reduced the dangers of many diseases. Providing pure supplies of water and food is very important in disease control. So is safe disposal of sewage. Control of insects that carry diseases is a must in some communities.

Alcohol and driving do not mix because alcohol, even in small doses, slows down reaction time. Slow reaction time results in accidents. Narcotic drugs are habit-forming. Their use often leads to crime and disease. Once started, the drug habit is very hard to break. The use of tobacco is likely to damage the body. Records indicate that nonsmokers live longer on the average than smokers do.

APPENDIX

Cell Structures and Functions

This chapter is for the student who would like to learn some additional details about cell structure and function. Many of these details were not known until very recent times. Some of them have resulted from use of the *electron microscope*. Others owe their origins to experiments in *biochemistry*, which may be described as the chemistry of life.

The electron microscope. The first rather simple electron microscope was put together in 1932. It was not a very good one, but later models were greatly improved. An electron microscope does not have any glass lenses like those of an ordinary optical microscope. Rather, it uses a stream of atomic particles called ***electrons.*** These particles pass through a vacuum tube, through the object that is being examined, and then an image is focused on a screen. The operator then photographs what appears on the screen if he wishes a permanent record of the magnified object. The microscope may look like the one shown in Fig. 2-3 on page 16.

A good optical microscope may magnify any part of a cell about 1,000 times but an electron microscope will magnify the same object 200,000 times or more. You can also enlarge an electron microscope photograph, thus making visible cell parts that are invisible by an optical microscope.

There is a limit, however, to what you can do with an electron microscope. You can, for instance, see groups of molecules, but you cannot see single molecules, to say nothing of the atoms that are in them. Just the same, you can see a lot of things that have long been mysteries. Some of them are shown in Fig. A-1, which is a diagram that shows some of the smaller cell structures.

Some new cell structures. In Fig. A-1 you can see that the *nuclear membrane*, which surrounds the nucleus, is really a double structure. You can also see the very large number of tiny dots. There are the microsomes. On them and in the open cytoplasm are much smaller particles called ribosomes. In Fig. A-1 see how the tiny microsomes are attached to membranes which form a network of tube-like channels all through the cytoplasm. This network is the *endoplasmic reticulum*. It is well developed in gland-type cells which secrete large amounts of protein materials. It is thought that the passageways formed by the reticulum deliver the cell product to where it can be passed out through the cell membrane. Many types of cells have very little endoplasmic reticulum.

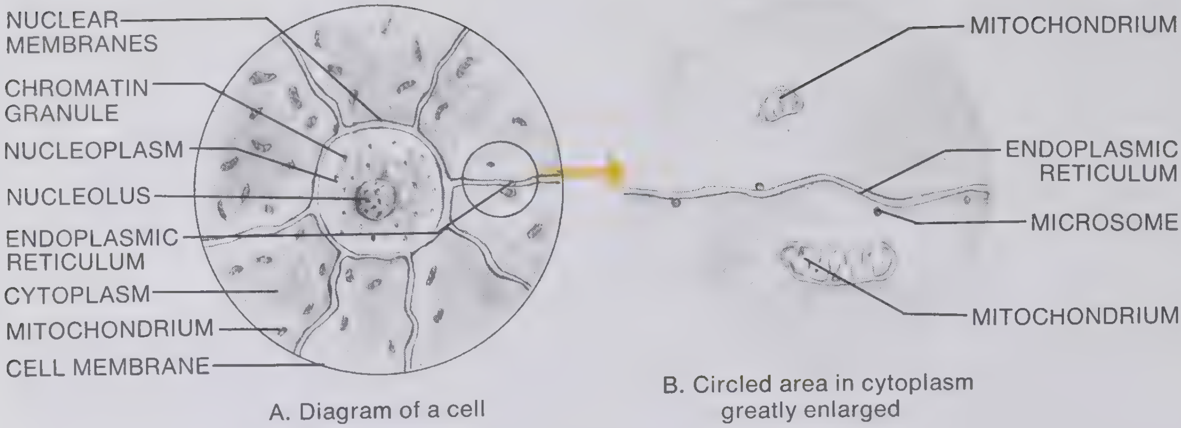


Fig. A-1. A diagram showing cell structure. The circled area of the cell has been greatly enlarged in the diagram at the right.

are a number of mitochondria. You already know something about them, but now notice their structure. They are covered by double membranes and these membranes reach across the inside cavity. Their enzymes are attached to these membranes.

In making microscope sections, mitochondria are cut at various angles. As a result, they may appear rodlike, or as ovals, or as small circles. They contain fat molecules, protein molecules, and small amounts of RNA and DNA. Among the protein molecules are *enzymes* that act to bring about oxidation. So a mitochondrium is a center where respiration goes on, and where energy to do the work of the cell is set free. Mitochondria are often called the "powerhouses of the cell." In Fig. A-1 you can see that they are much larger than microsomes. Apparently it is in the ribosomes that amino acids are joined together to form the proteins that the cell must have.

A microsome is joined to the endoplasmic reticulum. It is much smaller than a mitochondrium. In fact, about 10,000 microsomes are necessary to make up the bulk of a single mitochondrium. Upon the microsome are even smaller units. They are called *ribosomes*. The ribosomes contain protein molecules, a good deal of RNA, and enzymes. This is where scientists believe that amino acids unite to form the various proteins that cells need for their normal activity. Mitochondria and microsomes seem to occur in all kinds of cells.

Protein molecules. Protein molecules are relatively large and complex. The cell builds them by joining together smaller and simpler amino acids that are used by cells. The structural formulas of five of them are shown in Fig. A-2. You can see that the main parts of the five molecules are the same. But each of them has a *side group*, and the various side groups are different. The side group of glycine, for instance, is made up of a single hydrogen atom. The side group of alanine, however, contains three hydrogen atoms and one carbon atom. The various side groups are bonded to the main parts of their molecules as shown in the diagram.

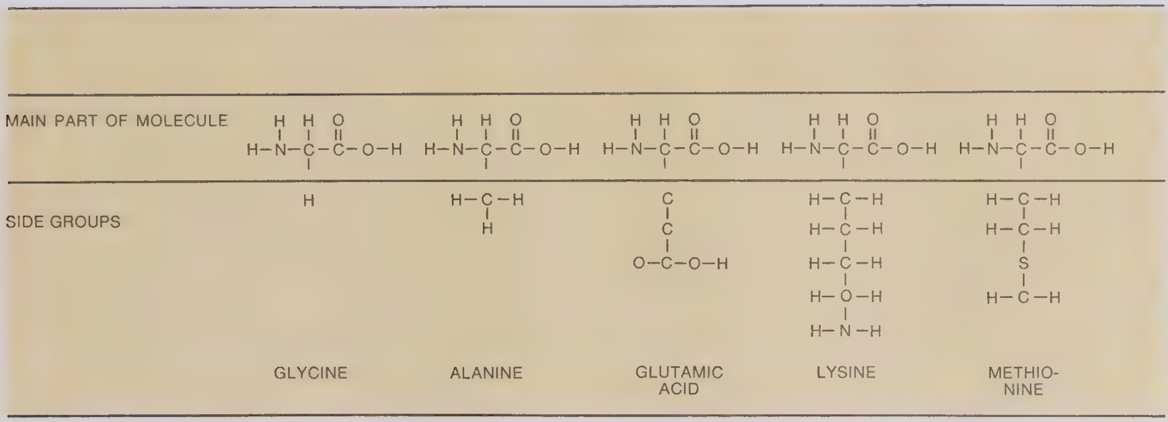


Fig. A-2. The structure of five amino acids. Note that each of them has a main part and a side group.

A protein molecule consists of a large number of amino acid molecules that are bonded together. Let us take glycine and alanine and see how they can be linked. This is shown in Fig. A-3. First, glycine loses one hydrogen atom, and alanine loses an oxygen atom and a hydrogen atom. Then the remaining parts of the two amino acids become bonded as shown in the

Fig. A-3. A diagram to show how two amino acid molecules (glycine and alanine) can be bonded together.

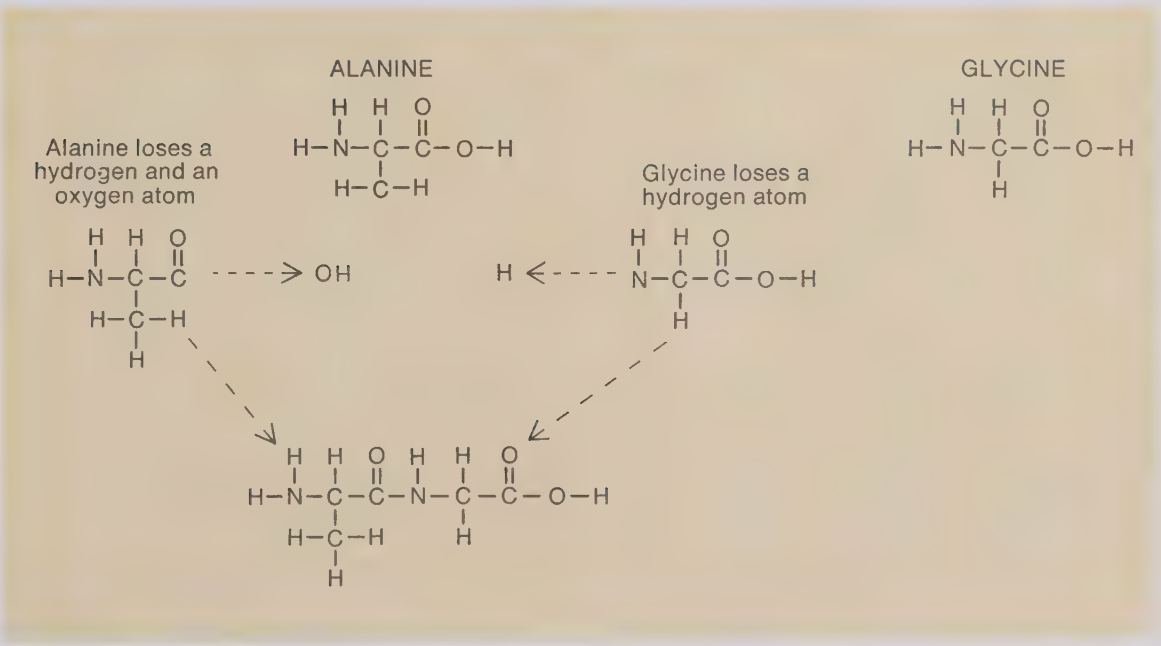


diagram. But remember that *many* amino acids must be linked together in order to have a protein molecule. Can you see now why we say that protein molecules are extremely large and complex?

Let us remember that 20 different amino acids are used to build cell proteins. Some of them appear in one protein but not in another. Sometimes they are linked together in one way, and sometimes in other ways. Some appear more often in one protein than they do in other proteins. So it is not surprising that there are many different kinds of proteins. Their amino acids are bonded to form *chains*. Two or more chains may be connected. Chains may also be twisted around each other or doubled back on themselves in very complex ways.

Energy is required to combine small molecules and make large, complex molecules. In the living cell this energy comes from ATP molecules. The ATP molecules lose their extra energy and some of their atoms and become ADP molecules. Now when a large, complex molecule breaks down, energy is released. This free energy is taken up by ADP molecules, together with a few needed atoms, and the ADP molecules become ATP molecules again. The ATP molecules are energy-charged, and they can now supply this energy for other chemical changes.

In the process of digestion, a protein molecule is broken down into amino acids again. This involves adding hydrogen and oxygen from water molecules. When you eat a protein that comes from beans, for example, it is broken down into amino acids. These amino acids are delivered to the cells of tissues. In the cells, some of the amino acids are recombined to form the proteins that the cell must have. But some of the amino acid molecules are not needed for this purpose so they are used simply as energy foods. The nitrogen part of their molecules is discarded as a waste.

The function of enzymes. Vast numbers of chemical reactions take place in cells, and each of them is speeded up by a particular type of enzyme. Enzymes are special types of proteins. This means that enzymes exist in great variety.

How does an enzyme molecule act to bond other molecules together? Here is one explanation that concerns the bonding of two sugar molecules. Two simple sugar molecules ($C_6H_{12}O_6$) are bonded to form a single, larger sugar molecule with the formula $C_{12}H_{22}O_{11}$. We think that the enzyme molecule first forms a temporary bond with each of the simple sugar molecules. The enzyme is shaped so that the two simple sugar molecules are held against each other. Now the simple sugar molecules react chemically, and become bonded to form a larger sugar molecule. A molecule of water is given off in this process. If you look again at Fig. A-3, you will see that a molecule of water was also given off when glycine and alanine were bonded. Now the new $C_{12}H_{22}O_{11}$ molecule separates from the enzyme molecule. The enzyme molecule is free to bond another pair of simple sugar molecules. The bonding reaction has been as follows:

$$C_6H_{12}O_6 + C_6H_{12}O_6 \longrightarrow C_{12}H_{22}O_{11} + H_2O$$

Note that the enzyme molecule

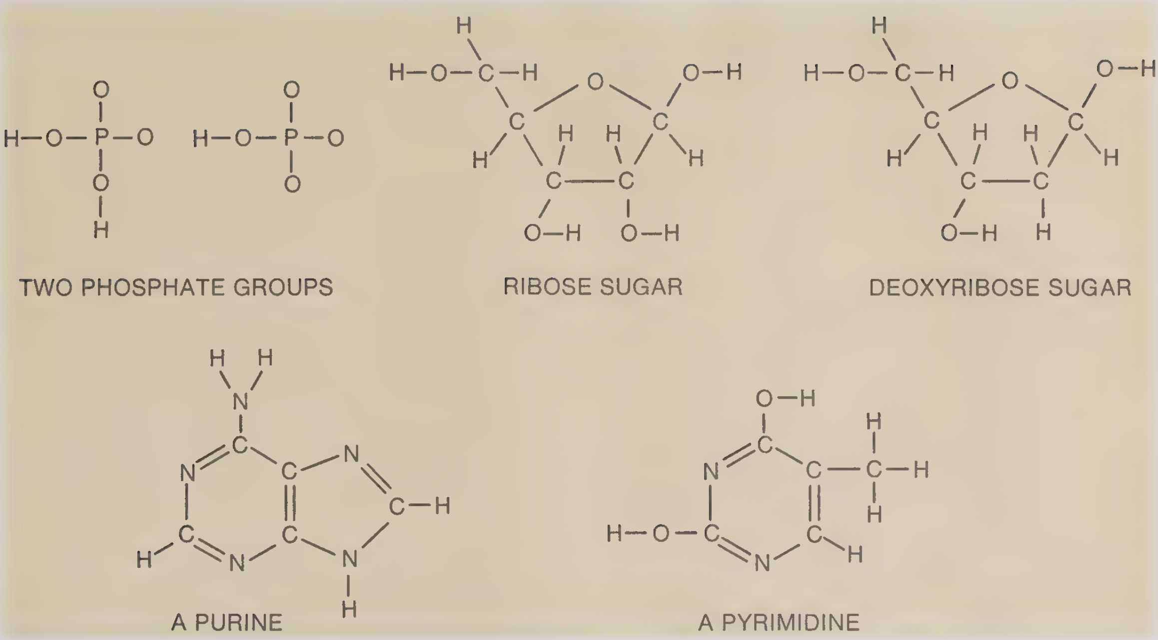


Fig. A-4. The structure of phosphate groups: ribose sugar, deoxyribose sugar, a purine, and a pyrimidine.

must have just the right pattern to form temporary bonds with the simple sugar molecules. This appears to be the reason why each type of enzyme can produce only one kind of chemical change. It also makes clear that what a cell can do depends on the kinds of enzymes the cell contains.

Where do enzymes come from? What causes a cell in an apple tree to have one group of enzymes, and a cell in a house mouse to have quite another group? These are good questions. To answer them, however, we must know more about the nucleic acids called DNA and RNA.

The general nature of nucleic acids. DNA, or deoxyribonucleic acid, appears to be the dominant and active material of the genes. It is found largely in the nuclei of cells. RNA, or ribose nucleic acid, is found both in nuclei and in cytoplasms.

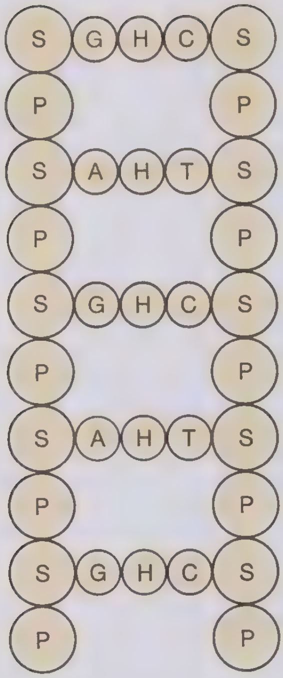
Like the proteins, DNA and RNA consist of smaller molecules or units that have been bonded together. We call these units ***nucleotides.*** Each nucleotide, in turn, contains three substances, as follows:

1. A *phosphate group* or unit, such as H_2P0_4 or $HP0_4$.

2. A *sugar group,* which is either *ribose sugar,* or *deoxyribose sugar,* as shown in Fig. A-4. When you look at this figure, note that deoxyribose sugar contains one less oxygen atom than ribose sugar.

3. Either a *purine* or a *pyrimidine group,* as shown in Fig. A-4. It may be seen in the figure that these are ring compounds.

A nucleotide is either ribose or deoxyribose, depending on what kind of sugar it contains. Its phosphate group is always the same. But the purine-pyrimidine combination varies. The nucleic acids contain two kinds of



S—Sugar unit
P—Phosphorus unit
T—Thymine
A—Adenine
C—Cytosine
G—Guanine
H—Weak hydrogen bond

Fig. A-5. A diagram to show how various chemical units are bonded in a nucleic acid molecule. Only a small part of the nucleic acid molecule is shown here.

purines called *adenine* and *guanine.* They contain three kinds of pyrimidines known as *cytosine*, *thymine*, and *uracil.*

Each molecule of nucleic acid contains hundreds of nucleotides, bonded together in various combinations. So there are many, many varieties of nucleic acids. But note this important fact: *RNA contains only ribonucleotides*, and *DNA contains only deoxyribonucleotides.* The ribose nucleotide are of four types which include (a) adenine - ribose - phosphate, (b) guanine - ribose - phosphate, (c) cytosine - ribose - phosphate, and (d) uracil-ribose - phosphate. Deoxyribonucleotides are also of four types, which are (a) adenine-deoxyribose phosphate, (b) guanine - deoxyribose - phosphate, (c) cytosine - deoxyribose - phosphate, and (d) thymine - deoxyribose - phosphate.

By this time you realize that a molecule of nucleic acid is large and complex. This single molecule may contain thousands of nucleotides. These nucleotides are bonded together to form chains. The way in which they are bonded is shown in Fig. A-5. Note that the "ladder sides" are made up of sugar and phosphate units. The "rungs" go from one sugar group to another. Each "rung" in this diagram consists of an adenine unit joined to a thymine unit by a weak hydrogen bond, or a guanine unit joined to a cytosine unit by a weak hydrogen bond. The "ladder" can separate into two halves when the hydrogen bonds are broken.

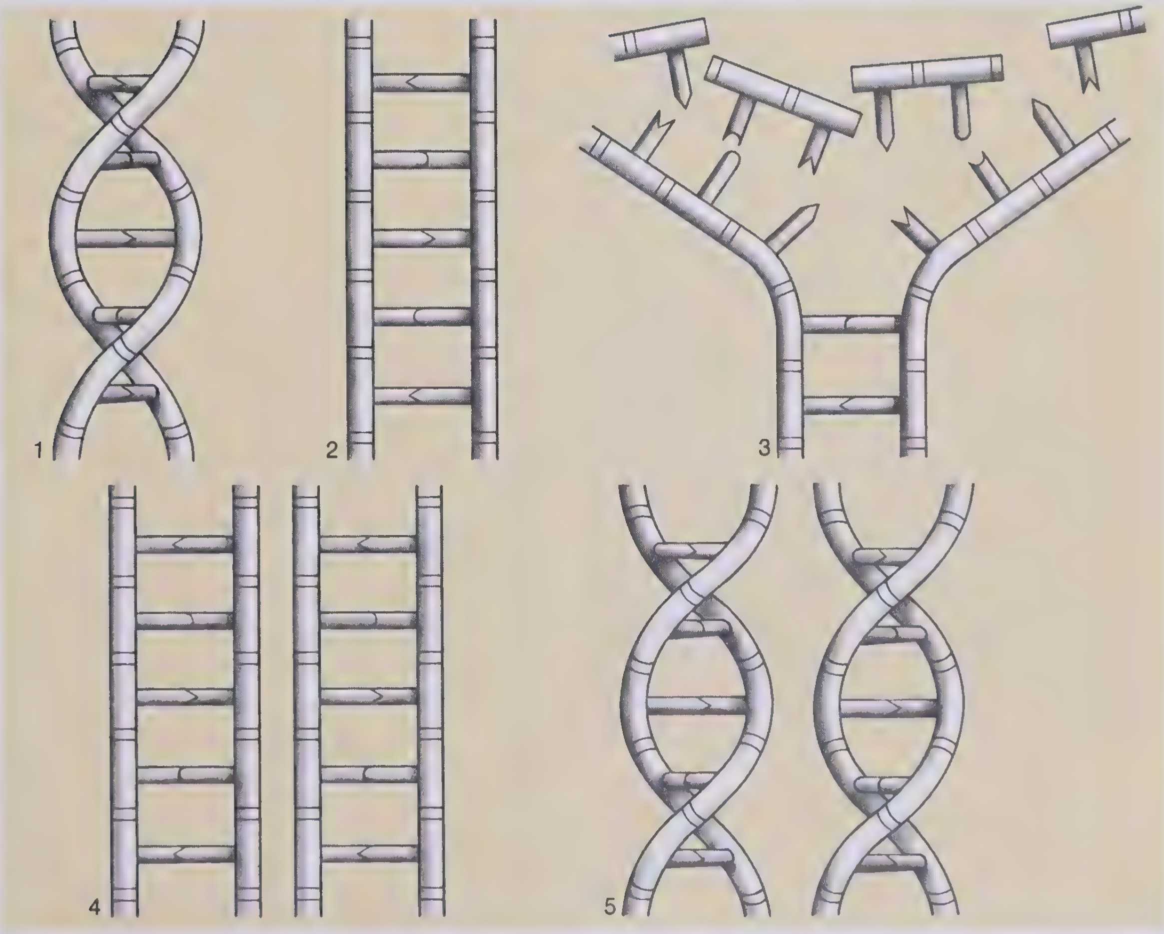
The DNA molecule and the gene. You might describe a DNA molecule as two chains of atoms that are held together by hydrogen bonds. They form a "ladder", with the purines and pyrimidines and their linking bonds in the "rungs" of the "ladder". The "ladder" is twisted into a spiral form, that is often called a *double helix.* A model of a DNA molecule, showing the manner in which its atoms are arranged, may be seen in Fig. A-7.

We are reasonabley sure that DNA is the substance of genes that carries the hereditary message. But not enough is known about gene structure to be sure what a gene looks like. As you know, genes are present in chromosomes, and there must be thousands of them in some cells. They

are very small, and this makes it difficult to learn more about them. One idea is that a gene may be made up of one or more DNA molecules grouped with one or more protein molecules. Or, the DNA molecules may be combined with protein molecules to form nucleoprotein molecules. But clearly, the gene contains DNA, and that is the important fact.

The DNA in the genes of a cell's nucleus determines what the cell can do, and what the cell will be. We do not know just how this is done, but we do have some evidences about certain things that happen. Before we describe these things we should know that a DNA molecule can reproduce or *replicate* itself. It can also produce a RNA molecule that will move out into the cell cytoplasm, and carry with it a definite "message".

Fig. A-6. This diagram shows how the DNA molecule is replicated. The helix unwinds as shown in 2. Then the weak hydrogen bonds in the "rungs of the ladder" are broken as shown in 3, and nucleotides formed from nutrients are added to each half of the "ladder" to replace its missing parts. The result is the formation of two DNA molecules as indicated in 4. These two molecules twist to form the helixes shown in 5.



A DNA molecule is replicated. As shown in Fig. A-1, the cell nucleus contains a mass of *nucleoplasm*. In this nucleoplasm are food materials or nutrients that can be used to build nucleotides. What happens to these nucleotides is shown in Fig. A-6.

First, the double helix of the DNA molecule unwinds, as shown in Fig. A-6(2). At this point the molecule looks like an ordinary ladder. Then the "rungs" of the "ladder" come apart in the middle, as in Fig. A-6(3). This means that the weak hydrogen bonds have been broken. Next, the nucleotides formed from nutrients are used to rebuild each half of the "ladder", which is also shown in Fig. A-6(3). When the two new "ladders" are assembled they look like Fig. A-6(4). Finally, the new "ladders" twist into the double helix as shown in Fig. A-6(5). Now the DNA molecule is replicated, and has become two identical DNA molecules.

Some molecules of RNA carry the message. DNA molecules of the nucleus produce RNA molecules in much the same way. A RNA chain is formed alongside a DNA chain from nucleotides of the nucleoplasm. After the RNA chain has been completed according to the DNA pattern, the RNA molecule separates from the parent DNA chain. The RNA molecule carries the same "message" that was in its DNA "parent". This RNA molecule is called messenger RNA. Its molecule may be made up of a single chain of nucleotides.

The messenger RNA enters the cytoplasm and makes contact with a ribosome. The ribosome moves along the length of the RNA molecule "reading" its message. The order in which the nucleotides are arranged guides the ribosome in putting amino acids together in the right order to make one, particular protein. A ribosome can build any protein. It must be guided by the messenger RNA to make just the right one, needed at that time. When one ribosome has moved part way along the RNA molecule others may follow behind it. In this way several molecules can be forming at one time.

During protein building the messenger RNA molecule is aided in its work by another much smaller type of RNA molecule. This smaller type of RNA molecule is called *transfer RNA*. The story of what happens begins in the cytoplasm away from the ribosome. Here a molecule of transfer RNA picks up one particular type of amino acid molecule and carries it to the ribosome. Other transfer RNA molecules bring to the ribosome the other types of amino acids that are needed.

At the ribosome, messenger and transfer RNA work together to produce an enzyme molecule. This is done by bonding the required amino acids in a certain order. The order follows the pattern carried by the messenger RNA molecule.

So you see that the "chain of command" goes from the DNA molecule to RNA molecules, and then to the enzyme. The enzyme gets the job done. As a result, a protein that is needed for growth and repair is supplied.

Now let us consider the case of a fertilized egg cell. In its chromosomes are the genes, and in the genes are the DNA molecules. The fertil-

ized egg cell is about to begin dividing. In other words, it is going to develop into a new individual. The particular DNA molecules in this cell through the "chain of command", will determine what the individual will be. It may be a cabbage plant, or a giant redwood tree, a catfish, or a cottontail rabbit. Its fate depends upon the DNA in the fertilized egg cell. For the DNA molecule brings to every fertilized egg cell a *genetic code*. One group of DNA molecules produces the redwood tree, and another group produces the rabbit. All this depends on the kinds of proteins and cells that are developed as a result of the genetic code.

In addition, what any one cell in a redwood tree or a rabbit does also depends upon the DNA in that cell's nucleus. So you can see that the DNA control exists in the fertilized egg cell, and also in every cell of an adult body. In the end, it is the enzymes that preside over cell life. But what the enzymes will be depends upon the genetic code of DNA molecules.

Earlier in this chapter we asked why an apple tree cell contained one group of enzymes, and a house mouse cell had another combination. Now we can answer this question. The tree and the mouse developed from different fertilized egg cells. The genetic codes of these two egg cells were not the same. The DNA pattern in the apple egg cell was one thing, and the DNA pattern in the mouse egg cell was another. The different genetic codes made it certain that the apple cell and the mouse cell would have different sets of enzymes.

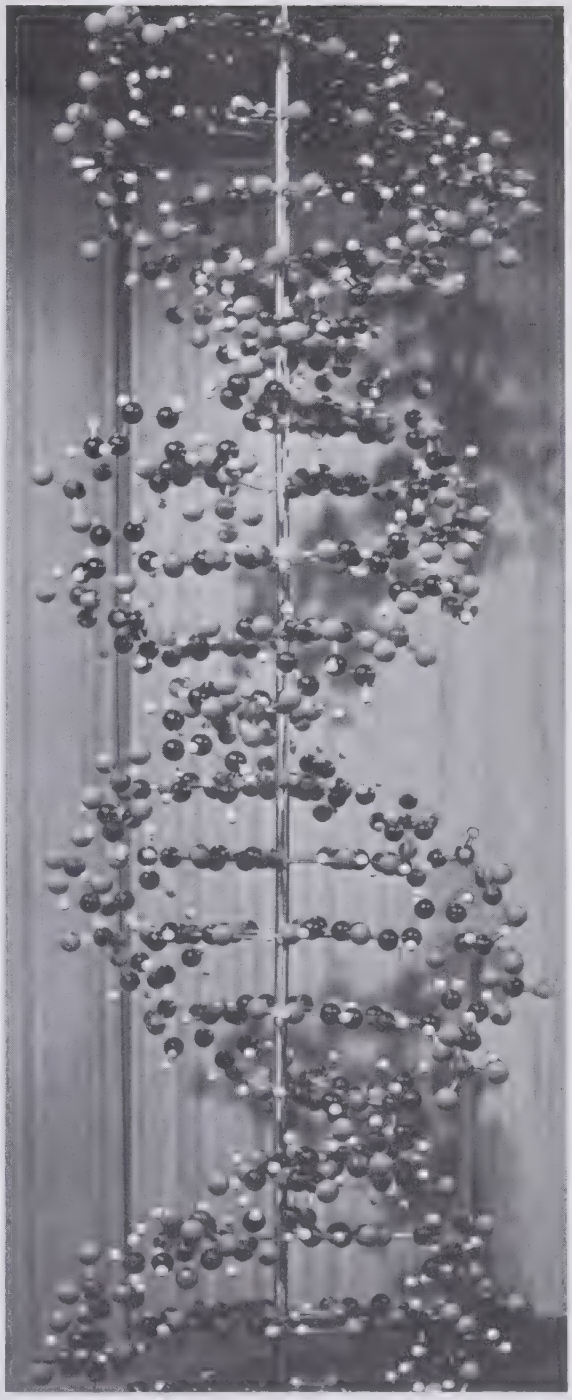


Fig. A-7. A man-made model to show the structure of a nucleic acid molecule. As you can see, such a molecule is very complex. (BBC, Broadcasting House, London)

Some unanswered questions. We now

have seen, in a general way, how a cell functions. Its many chemical activities are controlled by enzymes. The enzymes are formed in the ribosomes. The kind of enzyme produced by a ribosome is controlled by messenger RNA with help from transfer RNA. The nature of the RNA is controlled by DNA molecules in the genes of the nucleus. These DNA molecules can replicate themselves. Mitochondria are centers for cell respiration. The ribosomes can be called the cell's "protein factories".

Much of this is very new knowledge. DNA structure was discovered in 1953. The actions of messenger and transfer RNA were made known later on. The type of code carried by a DNA molecule was worked out only recently.

We still do not know what makes the DNA in a gene produce messenger RNA at just the right time. What force causes messenger RNA to move into the cytoplasm? What force causes some cells to become muscle cells, while other cells become nerve cells or gland cells? What makes the mitochondria release energy by respiration just when it is needed? What makes the chromosomes move apart during mitosis? The answers to these and a host of other questions is, "we do not know as yet."

Glossary

abdomen (ab-*doh*-men), in man, the part of the body cavity below the diaphragm. In insects, the segments of the body behind the chest region.

acne (*ak*-nee), a condition of the skin in which oil glands are infected.

adaptation, structure or behavior which adjusts a plant or animal to its environment.

adrenal (uh-*dree*-nul) **glands,** pair of ductless glands. One lies against the upper end of each kidney.

adrenalin (uh-*dren*-uh-lin), one of the many hormones secreted by the adrenal glands.

air sacs, tiny thin-walled sacs in the lungs containing networks of capillaries. Oxygen and carbon dioxide are exchanged in these sacs.

albino (al-*by*-noh), a plant or animal lacking pigment, or coloring matter.

algae (*al*-jee), several groups of simple green plants including kelps, rockweeds, *Chlorella*, and *Spirogyra.*

amphibians (am-*fib*-ee-uns), cold-blooded vertebrates such as frogs, toads, and salamanders. They are partly adapted to land and partly to water.

antibiotics (an-tuh-by-*ot*-iks), modern drugs that are taken from certain molds and bacteria. Some of them can also be made artificially.

antibody, a chemical substance in the body which destroys germs.

antiseptic (an-tuh-*sep*-tik), a chemical used to kill germs on the outside of the body.

anus (*ay*-nus), an opening at the end of the intestine through which undigested wastes pass.

appendage, an arm, leg, antenna, or similar structure attached to the body.

appendicitis (uh-pen-duh-*sy*-tis), a disease in which the human appendix is infected by bacteria.

appendix, structure attached to the large intestine in man. It has no function.

artery (*ar*-ter-ee), blood vessel which carries blood from the heart to body tissues.

arthropods (*ar*-throh-podz), phylum of animals without backbones that are segmented and have jointed appendages; includes the crustaceans, centipedes, millepedes, spiders, ticks and insects.

asexual reproduction, reproduction in which no sex cells are involved.

astigmatism (a-*stig*-ma-tism), a condition in which the eye surface is out of shape and produces a poor image.

ATP, a phosphorus compound found in living cells. It provides the energy for chemical changes. Its full name is *adenosine triphosphate.*

atoms, tiny units of matter which make up the elements.

auditory (*aw*-duh-tor-ee) **nerve,** a nerve that carries sensory impulses from the ear to the brain.

auricle (*or*-i-k'l), a chamber of the vertebrate heart that receives blood coming in from other parts of the body.

bacteria, one-celled protists that do not have nuclei. Many are parasites or feed on dead plants and animals.

bark, the part of the woody stem lying outside the cambium.

beriberi (*behr*-ee-*behr*-ee), a deficiency disease caused by lack of vitamin B_1.

bile, a fluid produced by the liver and stored in the gall bladder. It separates fats into small particles that can be digested.

bladder, an organ of the human excretory system which holds the urine until it can be discharged.

block cutting, the practice of cutting down blocks of trees, but leaving some other groups of trees to reseed the area.

blood vessel, a tube that carries blood.

budding, a type of reproduction in which a bulge is developed on the parent plant or animal. This bulge grows into a new individual.

calorie, a unit of heat energy; often used to describe the amount of energy in different foods.

cambium (*kam*-bee-um), a layer of growth cells in a plant stem.

capillaries (*kap*-uh-lehr-eez), tiny blood vessels in the body tissues. They form the connections between arteries and veins.

carbohydrates (kar-boh-*hy*-drayts), compounds of carbon, hydrogen, and oxygen that are the basic food substances of the cell. They include various types of sugar and starch.

cell membrane, a thin membrane that surrounds a cell and controls what enters and leaves.

cells, small units of living matter that make up the tissues of plants and animals. Some of them live independent lives as one-celled living things.

cell wall, the outer, nonliving covering of many plant cells.

cerebellum (sehr-uh-*bel*-um), a part of the brain having to do with balance and muscular control.

cerebrum (sehr-*uh*-brum), a part of the brain having to do with processes such as memory, thinking, and consciousness.

chlorophyll (*klor*-uh-fil), the green material in plants, used in making food.

chromosomes (*kroh*-muh-sohms), structures in the cell nucleus that contain the genes.

cilia (*sill*-ee-uh), short threads of protoplasm that extend out from some cells.

class, a classification group made up of related orders of plants or animals.

climax community, the type of community that becomes dominant at the end of a succession.

clot, a mass of blood which has become like thick jelly. It plugs wounds and stops bleeding.

cochlea (*kok*-lee-uh), a coiled hearing structure of the inner ear.

coelenterates (suh-*len*-ter-ayts), the phylum that includes *Hydra,* jellyfishes, corals, and sea anemones.

colony, a group of plants or animals living together.

community, all the plants and animals that live together in a local environment.

compound, two or more elements united in definite amounts to form a sub-

stance that has its own special properties.

compound eye, a type of eye made up of many small eye units packed together; found in some arthropods.

consumer, a plant or animal that cannot make its own food.

cornea (*kor*-nee-uh), a transparent, curved front part of the eye that acts as the outer lens.

crop, the enlarged part of the digestive canal of an earthworm that holds food until it can be digested in some other part of the intestine.

crop rotation, the practice of not planting the same crop on the same ground every year, so that no one mineral is used up too rapidly.

cutting, part of a root, stem of leaf from which a new plant may be grown.

cyst (*sist*), a protective covering that some protozoans and parasitic worms form around themselves.

cytoplasm (*sy*-toh-plazm), the mass of protoplasm between the nucleus and cell membrane.

deficiency (duh-*fish*-en-see) **disease,** a disease caused by lack of some vitamin.

dentine (*den*-tine), a hard, bonelike substance under the enamel and forming the main body of the tooth.

diabetes (dy-uh-*bee*-teez), a disease due to lack of insulin, in which the body is unable to use sugar.

disinfectant (dis-in-*fek*-tunt), a powerful germ killer.

DNA, a nucleic acid found in the genes of cells. Its full name is deoxyribose nucleic acid.

dominant trait, a trait that develops even when only a single dominant gene is present.

drug addiction, physical and mental dependence on a narcotic.

duct, a tube through which liquids can flow from a gland.

ductless gland, a gland that discharges its secretion directly into the bloodstream.

eardrum, a membrane stretched across the opening of the middle ear. Sound waves cause it to vibrate.

egg cell, a female reproductive cell.

element, any one of 92 basic substances found in nature. Each element is made up of atoms which are all more or less alike and are different from the atoms in any other element.

embryo (*em*-bree-oh), an early stage in the development of a complex plant or animal.

enamel, extra-hard, white material on the outside of the tooth.

energy, the ability to do work.

environment, all of the things and forces that surround an individual.

enzyme, a protein which controls some particular chemical change in a cell.

esophagus (uh-*sof*-a-gus), a tube leading from the throat to the stomach.

excretion (eks-*kree*-shun), the process in which living things get rid of wastes.

family, a classification group made up of related genera of plants or animals.

fats, compounds found in protoplasm, and often used as sources of energy.

feces (*feh*-seez), undigested wastes which leave the intestine.

fermentation, a type of respiration in which molecules are changed to release energy without the use of oxygen.

fertilization, the union of an egg cell with a sperm.

fertilizers, decaying plant and animal

materials, or chemicals made in factories, which add useful minerals to the soil.

fever, a body temperature above the normal range.

flagellum (fluh-*jell*-um), a thin strand of protoplasm that extends out from a cell. Its lashing serves to move the cell in some cases.

flatworms, a phylum of animals that have flattened bodies and an intestine with a single opening; includes *Planaria*, flukes, and tapeworms.

food chain, the passing along of food as animal A eats plants, animal B eats animal A, and so on.

fossil, a record of past life such as an imprint, a bone, or a shell that has been preserved in the rocks.

fruiting body, an organ of a fungus that produces spores.

functional disease, one in which some part of the body fails to function as it should but not because of an infection.

fungi (*fun*-jy), a large group of non-green plants including the yeasts, molds, mushrooms, puffballs, and shelf fungi.

gall bladder, a sac in which bile is stored until it is discharged into the intestine.

gastric juice, a digestive juice produced by the stomach glands, containing an acid and enzymes.

gene pool, the genes in the sex cells of any total adult population of plants or animals.

genes (*jeens*), units in chromosomes that affect heredity and control cell activities.

genus (*jee*-nus), a classification group made up of related species of plants or animals.

gizzard, a muscular part of the intestine of an earthworm that grinds up coarse foods.

glucose (*gloo*-kohs), the most important of the simple sugars found in living things.

grafting, making the stem or bud of one plant grow on the stem of another plant.

growth ring, a ring of water-carrying tissue in a tree trunk. One ring is formed in each growing season.

guard cell, one of the cells surrounding a leaf pore. Guard cells contract and expand to close and open the pores, and thus regulate the amount of water that escapes.

heredity (her-*ed*-uh-tee), the passing along of characteristics from one generation to another.

hormone (*hor*-mohn), a chemical compound produced by a ductless gland. It influences cells in other parts of the body.

host, a plant or animal upon which a parasite feeds.

humus, (*hew*-mus), decaying plant and animal material in the soil.

hybrid, a plant or animal having opposed genes for a given character.

immunity, the state of being unable to get a disease.

insects, a class of arthropods. They have six walking legs, and their bodies are divided into a head, chest, and abdomen.

instinct, a complex series of reflex actions. It depends on the inherited nerve structure.

insulin (*in*-suh-*lun*), a hormone produced by cells in the pancreas; needed for the body to use its sugar normally.

iris (*eye*-rus), a colored part of the eye in front of the lens.

larva (*lar*-va), any young animal that is

very different from the adult, such as a caterpillar or a tadpole.

lens, a structure in the eye which helps form the image on the retina.

lichen (*ly*-ken), a plant combination in which an alga lives with a fungus and both benefit.

ligament, a type of strong, tough connective tissue that holds two bones together.

loam, a type of soil that contains a mixture of particle sizes.

lymph (*limf*), a clear liquid similar to plasma, which is found in the lymph vessels.

lymph nodes, glandlike swellings in lymph vessels. They contain white blood cells which destroy germs.

mammals, warm-blooded, air-breathing animals with backbones, and bodies more or less covered with hair; the only animals that produce milk to feed their young.

mantle, a thin layer of flesh that produces the shell in mollusks.

matter, anything that takes up space and has weight.

medulla (muh-*duhl*-uh), a part of the brain that helps to control breathing, heartbeat, and blood pressure.

mitosis (my-*toh*-sus), nuclear division in which two equal groups of chromosomes are formed.

molecule, the smallest natural unit of a compound.

mollusks (*mol*-usks), a phylum that includes the clams, oysters, snails, slugs, squids, and octupuses.

motor nerve cells, nerve cells that control gland and muscle action.

mutation (myoo-*tay*-shun), a new characteristic that can be inherited. It is caused by some change in a gene.

narcotics, habit-forming drugs of the cocaine and morphine type.

natural enemies, other animals that use a certain species as food.

nematode (*nehm*-uh-*tohd*), another name given to the roundworms.

nerve, a bundle of nerve fibers surrounded by a sheath.

nerve impulse, a change in electrical charge that travels along a nerve fiber; the "message" carried along a nerve fiber.

niacin (*ny*-uh-*sun*), a vitamin needed for the proper use of carbohydrates.

nitrates, certain compounds containing nitrogen. Green plants use nitrates in making proteins.

nitrogen cycle, a cycle that takes place in nature. Bacteria of decay break down dead materials and produce nitrates. Other bacteria break down nitrates. Also, nitrogen of the air is used by nitrogen-fixing bacteria to make nitrates. Nitrates are used by plants to build proteins.

nitrogen-fixing bacteria, certain bacteria that are able to combine nitrogen with other elements to form nitrates.

nitrogenous (*ny-troj*-en-us) **wastes,** nitrogen compounds that are the waste products of protein breakdown.

nuclear membrane, a double membrane that surrounds the nucleus of a cell.

nucleic acid, a substance that is either DNA or RNA. Both of these nucleic acids appear in many different forms.

nucleus (*noo*-klee-us), a dense, inner structure found in cells. It controls most of the cells' activities.

nymph (*nimf*), a growth stage in the life cycle of a grasshopper and some other insects.

optic nerve, a nerve connecting the nerve cells of the retina with the brain.

order, a classification group made up of related families of plants or animals.

organ, a group of tissues that forms a

working unit such as a stomach or an eye.

ovary (*oh*-vuh-*ree*), an organ which produces egg cells.

oxidation, a process in which a substance unites with oxygen.

pancreas (*pan*-kree-us), a gland that produces a digestive juice and also the hormone insulin.

parasite, a plant or animal that feeds on a host. It may live on the host or in it.

parathyroids, four small ductless glands in the neck region. They regulate the amount of calcium salts in the bloodstream.

pasteurization, the process of heating a substance enough to kill dangerous germs, but not enough to change its flavor greatly.

pellagra (*pell*-lay-*gruh*), a deficiency disease due to lack of niacin.

photosynthesis (*foh*-toh-*sin*-theh-sus), the process in which green plants make food.

phylum (*fy*-lum), a classification group made up of related classes of living things.

pituitary (puh-*too*-uh-*tehr*-ee), a ductless gland at the base of the brain; it produces hormones that affect the action of other glands.

pit vipers, a snake group which includes the rattlesnakes, the copperhead, and the water moccasin.

placenta (pluh-*senn*-tuh), a structure that surrounds and nourishes some developing mammals before birth.

plasma (*plaz*-muh), the liquid part of the blood.

platelets, tiny structures found in the blood. They break down when they touch a cut or rough surface. This breakdown causes the clotting of blood to begin.

pollen grains, tiny grains produced by the stamens of a flower and containing the sperm cells.

pollution, impurity of water usually due to dumping sewage and factory wastes into lakes, streams, or the sea.

population, the members of any species that live in a given community.

primates, an order of mammals including monkeys, lemurs, apes, and man.

producer, a living thing that can manufacture its own food. Green plants are the most important producers.

proteins (*proh*-tee-uns), the most important compounds of protoplasm. They contain carbon, hydrogen, oxygen, and nitrogen, and sometimes phosphorus and sulfur.

protoplasm (*proh*-toh-plasm), the living substance.

protozoa (*proh*-toh-*zoh*-uh), a group of small, simple living things. Many of them exist as single cells.

pupa (*pyoo*-puh), a resting stage in the development of some insects.

pupil, a circular opening in the iris of the eye through which light rays enter.

recessive trait, one that does not develop if the corresponding dominant gene is present.

red blood cells, cells containing the red iron compound that carries oxygen.

reduction division, the separating of each pair of similar chromosomes in the formation of a sperm or egg cell.

reflex, one type of automatic response to a stimulus.

reproduction, the process in which plants and animals produce more of their own kind.

reptiles, cold-blooded, air breathing animals with backbones and scales. Lizards, snakes and turtles belong to this group.

respiration, the oxidizing of a food substance to provide energy.

response, a reaction to a stimulus.

retina (*ret*-uh-nuh), a layer of nerve cells sensitive to light in the back of the eye. The image forms on the retina, from which impulses are sent to the brain.

rickets, a deficiency disease due to lack of vitamin D.

rickettsiae (*rik*-ett-*see*-ee), a group of very small parasites that cause a number of diseases.

RNA, one of the nucleic acids. Molecules of DNA make corresponding molecules of RNA. The full name of RNA is ribose nucleic acid.

root cap, a mass of cells that covers and protects the growing tip of a root.

root hair, a hair-like part of a cell on the surface of a root that is well suited for absorbing water.

roundworms, a phylum of unsegmented worms with an opening at either end of the digestive canal; it includes *Ascaris,* hookworms, the trichina worm, and vinegar eels.

saliva (suh-*liv*-uh), a juice produced by glands near the mouth. It moistens food and contains an enzyme which digests starch.

scavenger, an animal that eats dead animals.

scurvy, a deficiency disease due to lack of vitamin C.

segmented worm, a phylum of worms that are divided into sections, including the earthworms, leeches, and sandworms.

selective cutting, the practice of cutting just the mature trees of a forest.

semicircular canals, organs of balance in the inner ear.

sensory nerve cell, a type of nerve cell that receives a stimulus from the sense organs and relays it inward.

sex-linked trait, a trait carried only in the X chromosome.

sexual reproduction, reproduction following the union of two sex cells.

sheet eroison, the wearing away of the entire soil surface.

siphon (*sy*-fun), a tube in mollusks through which water passes.

soil depletion (dee-*plee*-shun), loss of fertility because too much of the mineral compounds have been drawn from the soil by crops.

special senses, in man, the senses of sight, hearing, balance, taste, smell, pressure, heat, cold, pain, and muscular effort.

species (*spee*-sheez), a distinct kind of living thing.

sperm, a male reproductive cell.

spleen, an organ in the abdomen which helps destroy germs, worn-out red blood cells and poisons.

stimulus (*stim*-yoo-*lus*), anything which calls forth a response by a plant or animal or by some part of its body.

strip cropping, the practice of alternating strips of different crops across the hillside.

subsoil, the layer of soil beneath the topsoil.

succession, a series of different types of communities replacing one another in order. Finally, a more or less stable climax growth becomes dominant.

system, a group of organs working together to perform one general function such as digestion.

taste buds, groups of cells on the top and sides of the human tongue that are sensitive to taste.

tendons, tough cords of connective tissue that attach muscles to bones.

testes (*tes*-teez), organs that produce sperms.

thyroid, a ductless gland in the neck region. It produces a hormone that affects the rate of oxidation in the body.

tissue, a group of similar cells which carry on the same kind of activity.

tissue fluid, a fluid that has escaped from blood plasma; it bathes the cells of tissues.

topsoil, the surface layer of soil that contains humus.

tube feet, flexible tubes of starfish and their relatives, used in holding on to solid objects by suction.

tundra, a type of community having only small plants, found north of the tree line and above it.

umbilical (um-*bill*-ee-*kul*) **cord,** a structure that connects an unborn mammal with the placenta.

urea (yoo-*ree*-uh), a nitrogenous waste formed by the liver from ammonia wastes.

urine (*yoo*-rin), a mixture of water and dissolved wastes that is drawn off by the kidneys and excreted from the body.

uterus (*yoo*-ter-us), a structure in female mammals that holds the embryo during development.

vaccine (*vak*-seen), a substance used to produce immunity to a given disease.

vacuoles (*vak*-yoo-*ohls*), spaces in the cytoplasm of cells which may contain stored food, water, or waste substances.

vascular (vas-*kyoo*-lur) **tissue,** in plants, tube-shaped cells that carry liquids.

vascular bundle, a duct made up of vascular tissue in a plant.

vascular plant, a plant having vascular tissue. Included in this group are the club mosses, horsetails, ferns, and seed plants.

vegetative reproduction, a type of asexual reproduction in which some part other than a seed or spore grows into a new plant.

vein, in animals, a blood vessel that carries blood from the tissues to the heart. In plants, a vascular bundle in a leaf.

ventricle (*ven*-tri-k'l), a chamber of the vertebrate heart that pumps blood to the lungs or other parts of the body.

vertebra (*ver*-tuh-*bruh*), any one of the bones that make up the backbone.

vertebrates, animals having backbones.

villi (*vil*-eye), small, finger-shaped bulges of the small intestine lining that absorb dissolved food.

virus, a tiny particle that contains DNA or RNA, and is active as a parasite within a host cell. Viruses cause many diseases of plants, animals, and man.

vocal cords, structures in the voice box that vibrate to make sound.

warm-blooded animal, an animal which oxidizes its food so rapidly that its body is kept warm all the time.

water cycle, the constant movement of water from ocean to land and back to ocean again.

watershed, the higher slopes and ridges at the upper end of a river valley.

water table, the water level at the top of a water-soaked region in soil.

white blood cells, several types of blood cells similar to amebas; some of them destroy germs.

woody stem, a type of stem that has water-carrying tissue in large masses of thick-walled cells; these cells become what we call wood.

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